

UDC 94(4):[355.3:623.1]“1850/1914”
DOI 10.24919/2519-058X.25.269539

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Bibliographic Description of the Article: Voitovych, L. & Kryvyziuk, L. (2022). Evolution of European Fortification in 1850 – 1914. *Skhidnoievropeyskyi Istorychnyi Visnyk [East European Historical Bulletin]*, 25, 80–91. doi: 10.24919/2519-058X.25.269539

EVOLUTION OF EUROPEAN FORTIFICATION IN 1850 – 1914

Abstract. *The purpose of the study is to do research on the issues of the European fortification evolution during the period of understanding and giving up the dominant ideas of the bastion and polygonal defense systems of fortresses to the completion of preparations for World War I in the second half of the 19th and at the beginning of the 20th centuries. The research methodology is based on the use a set of methods: dialectical, analytical, historical, biographical, comparative. This methodological approach allowed to analyze and reveal the factors that influenced the evolution retrospectively (exhaustion of bastion defense system and solid fortress fence, the emergence of high-explosive bombs and the implementation of shooting from closed positions), new ideas for defense and fundamental changes in fortifications, use of concrete and reinforced concrete, machine guns), location, types and features of long-term fortifications and discussions around the principles of defense, creation of new infrastructure with a network of railways, highway and railway bridges. The scientific novelty of the obtained results consists in a comprehensive analysis of periodization of the European fortification evolution during the period under analysis. The main differences and borrowings among different national schools of fortification science, interaction within military and political coalitions, the impact of financial opportunities on projects and changes in political conditions (especially on the example of the Austro-Russian relations), as well as military intelligence activities, in particular “Riddle’s case”.*

The Conclusion. Under the influence of turbulent changes in the scientific and technological revolution in 1850 – 1914, the evolution of the European long-term fortification took place. There was a complete rejection of the bastion and polygonal defense systems, a solid fortress fence. New ideas for defense and principles of fortification change survived a few short, but intense periods. In 1850 – 1870 it was necessary to replace the solid fortress fence with a belt of forts, located at the distance of 600–800 m from each other. In 1870 – 1880 interim batteries appeared, in 1880 – 1886 the offensive period was characterized by the location of forts at the distance of 5–8 km from the core of the fortress, which were higher the ground level, with the use of *poterne* for protection of soldiers and warehouse. In 1886 – 1899 the use of high-explosive bombs led to an intensive search of shelter, which culminated in the last stage, in 1899 – 1914, in the appearance of concrete and reinforced concrete fortifications, armored rotary towers, etc., which was also encouraged by the introduction of firing from closed artillery positions.

Key words: fortification, bastions, *tenaille*, forts, high-capacity bombs, shrapnel, concrete, reinforced concrete, reserved towers, defensive of *Halychyna*, *tete-de-pons*, Przemysł, Mykolaiv, Verdun, Namiur, Antwerpen.

ЕВОЛЮЦІЯ ЄВРОПЕЙСЬКОЇ ФОРТИФІКАЦІЇ У 1850 – 1914 рр.

Анотація. Мета статті – дослідити проблеми еволюції європейської фортифікації у період від осмислення і відходу панівних наполеонівських ідей до завершення підготовки до Першої світової війни у другій половині XIX – на початку XX ст. **Методологія дослідження** полягає у використанні сукупності методів: діалектичного, аналітичного, історичного, біографічного, порівняльного. Застосований методологічний підхід дав змогу ретроспективно проаналізувати і розкрити чинники, які вплинули на саму еволюцію (вичерпання можливостей бастионної системи оборони і суцільної фортечної огорожі, поява фугасних бомб і реалізація стрільби із закритих позицій), нові ідеї побудови оборони і принципи зміни фортифікації в означений період (використання бетону та залізобетону, мітральєз і кулеметів), розташування, типи і особливості довогочасних укріплень та дискусії навколо принципів оборони, створення нової інфраструктури з мережею залізниць, залізничних і шосейних мостів. **Наукова новизна** одержаних результатів полягає у комплексному аналізі процесу періодизації еволюції європейської фортифікації в цей період. Досліджено основні відмінності і запозичення між різними національними школами фортифікаційної науки, взаємодію у рамках військово-політичних коаліцій, вплив фінансових можливостей на реалізацію проєктів та змін політичної кон'юнктури (передовсім на прикладі австро-російських відносин), а також діяльності військових розвідок, зокрема “справи Редля”. **Висновки.** Під впливом бурхливих змін науково-технічної революції у 1850 – 1914 рр. протікала еволюція європейської довогочасної фортифікації. Відбулася повна відмова від бастионної та наступної полігональної систем оборони і відхід від суцільної фортечної огорожі. Нові ідеї побудови оборони і принципові зміни фортифікації пережили кілька короткочасних, але інтенсивних періодів. У 1850 – 1870 рр. відбувалася заміна суцільної фортечної огорожі поясом фортів, розташованих на віддалі 600–800 м один від одного. У 1870 – 1880 рр. з'явилися проміжні батареї, наступний період (1880 – 1886 рр.) характеризувався розташуванням фортів на віддалі 5–8 км від ядра фортеці на підвищеннях з використанням *потерн* для захисту як особового складу так і матеріальної частини. Застосування фугасних бомб зумовило у 1886 – 1899 рр. інтенсивні пошуки захисту, які вилилися на останньому етапі (1899 – 1914 рр.) у появі бетонних та залізобетонних укріплень, броньованих поворотних башт тощо, до чого підтиховувало і запровадження стрільби із закритих артилерійських позицій.

Ключові слова: фортифікація, бастиони, *теналі*, форти, фланкування, фугасні бомби, шрапнель, бетон, залізобетон, броньовані башти, оборона Галичини, *тот-де-пони*, Перемисьль, Миколаїв, Верден, Намюр, Антверпен.

The Problem Statement. After several centuries of use and improvement of the *bastion system* of fortresses defense and its continuation, i.e. *the polygonal system*, from the middle of the 19th century, there were fundamental changes in the long-term fortification systems, which continued until the beginning of World War I. The reasons for these changes, their

periodization and consequences remained unresearched. This process was stimulated by the scientific and technological revolution. The unresearched details of the European fortification evolution in 1850 – 1914 remain an important scientific issue, elucidation of which is the objective of our research.

The Analysis of Recent Research and Publications. In European historiography there was no focus on the coverage of the European fortification evolution which took place in 1850 – 1914. In fact, only in the first research papers of the prominent fortification engineers: the French general J. Benoit (Benoit, 1921, pp. 8–41, 113–137; Benua, 1922, pp. 1–27) and the Russian general of the Ukrainian origin K. Velichko (Velichko, 1922), written after the end of World War I, there was analysis of this issue in order to justify the national schools traditions of fortification science. In further research papers there was focus on advantages and disadvantages of individual fortification objects mainly. The lack of analysis of the European fortification evolution determines **the topicality** of our research, which aims at filling in this gap not only in Ukrainian, but also in European historiography.

The purpose of the article is to do research on the issues of the European fortification evolution during the period of understanding and giving up the dominant ideas of the *bastion* and *polygonal* defense systems of fortresses to the completion of preparations for World War I in the second half of the 19th and at the beginning of the 20th centuries.

The Results of the Research. Napoleon, a recognized genius of offensive maneuver warfare, defined the importance of fortresses as follows: “*A fortress is the only means of stopping, creating a problem, weakening, disturbing the winner. Fortresses create a convenient field of action for weaker armies in order to hold back and stop the enemy, and if there is an opportunity to attack the enemy, finally to buy time and wait for help*” (Napoleon, 2003, pp. 713–714).

From ancient times, fortresses were built with a continuous front of a circular defense. From the second half of the 15th century, with the appearance of fire artillery the introduction and improvement of the bastion defense system perfected a circular defense of fortresses. *The bastion fronts*, reinforced by *ravelins*, *tenaille* and *cavaliers*, made it possible to reduce the thickness of curtains, removing the main defensive load from them and thereby reducing garrisons of fortresses. The French marshal Sebastien de Vauban le Pretre (1633 – 1707) was the most outstanding fortification engineer of that time, who built 33 fortresses and modernized more than 300, taking part in 53 sieges (Alent, 1805, pp. 45–526; Auger, 1998; Auger, 2007; Barros, Salat, & Sarmat, 2006; Blanchard, 1996; Blomfield, 1938; Bornecque, 1984; Vauban and the French, 2009; Virol, 2003; Voban, 1912, pp. 445–448; Halévy, 1924; Herbert & Rothrock, 1990; d’Orgeix, Sanger & Virol, 2007; Duffy, 1985; Lazard, 1934; Langins, 2004; Le Brun, 2016; Mary, 2007; Monsaingeon, 2007; Paddy, 2006; Parent & Verroust, 1971; Parent & Verroust, 1982; Prost, 2007; Pujo, 1991; Jean-Denis, 2010) suggested three methods of *engineering successive attack* of fortresses (Vauban, 1793; Vauban, 1829; Vauban, 1841; Voban, 1744), which allowed to invade any fortress protected by a bastion front.

S. de Vauban also conducted research and testing of powder mines at training grounds and improved them for a long time (Barros, Salat & Sarmat, 2006; Herbert & Rothrock, 1990).

S. de Vauban’s successors tried “to save” the bastion system, they gave an impact to the evolution of fortification, which consisted in introducing fundamental changes from the middle of the 19th century.

The last major improvement of the bastion system was carried out by the French engineer Major-General Louis de Cormontagne (1696 – 1752). He supported the idea of big bastions with the second lines of defense. Big *ravelins* were to cover the *curtains* completely. In

polygonal structures with eight or more sides, ravelins were protruded far forward, so that when stormers reached the crest of *glacis*, ravelins could fire on them from the rear, to force the enemy to take two ravelins before storming the bastion. The stone masonry in front was covered with soil, which dampened the impact force of the nuclei. Later, it was recommended to place a separate ravelin, called a *lunette*, near the sole of *glacis* on the capital of bastion. Later, this idea of ravelin protruded towards the sole of the *glacis* was developed by Henri Jean Baptiste Bousmard (1749 – 1807), a French émigré in the Prussian service who headed the defense of Danzig in 1807. L. de Cormontagne developed the analysis, according to which the term of possible defense of this or that fortress was determined in case of a correct engineering attack according to Vauban. After this term, the surrender of fortress was not considered a war crime. The majority of L. de Cormontagne's provisions were top secret, classified and published according to Bayard's manuscripts already in Napoleon's time (Quevres, 1806; Quevres, 1808; Quevres, 1809).

The French Major-General of Cavalry and military engineer Marquis Marc René de Montalembert (1714 – 1800) in his treatise "Perpendicular Fortification, or Experiment in the Study of Different Ways of Fortifying a Straight Line, Triangle, Square, and All Polygons" (1776) rejected the idea of bastions in favour of a polygonal system (i.e. *tenaille* system) (*tenaille* (in French *tenaille* – tongs) – fortifications located at an incoming angle (most often obtuse up to 180 degrees) so that the terrain in front of them can be provided with cross defense. In the bastion system, *tenailles* were located in front of curtains, as a rule, continuing the lines formed by facades of neighbouring bastions, while reducing the risk of destroying curtain by artillery fire and serving to conduct rifle fire in defense of ditch. *Tenailles* were covered with *ravelins* (there was *poterne* in the center for access to ravelin). If there was a gate in the curtain, then a gap was made in *tenaille*, through which entrance road passed (Zuborowski, 1978, p. 263; Rüstow, 1843). The core of fortress consisted of a number of casemates with 1 – 2 tiers of guns. The stonework was covered with ground counterguard – *a kuivr-fas*, which had the second ditch in front. The ditch was flanked by casemates, which were located at incoming corners of counterguard and were covered by a parapet of a *reduit* or *lunette* on incoming bridgehead. The principle of defense was reduced to maintaining such fire that would not allow the enemy to place breach-batteries. In his ideas, M. de Montalembert completely rejected ground fortifications in favour of high casemate batteries with 4–5 tiers of guns, the masonry of which was protected only by cannon fire. 348 guns could, in his opinion, defend anything on the 450–460 m front. M. de Montalembert's work faced harsh criticism by opponents. Responding to them, he wrote 11 more volumes in which he developed his ideas, including the rejection of ground fortifications (1786 – 1793) (Vvon, 2003; Montalembert, 1776; Montalembert, 1786 – 1793).

In 1803, the English officer Henry Shrapnel (1761 – 1842) created the first projectile (a card grenade), which was named *shrapnel* in his honour (Hogg, 1970, p. 180; Nilus, 1904, p. 401; Sweetman, 2015, pp. 365–386). Open bastion sites became too vulnerable. A leading Austrian military fortification engineer Archduke Maximilian d'Este (1782 – 1863) suggested replacing bastions with casemate towers, erecting 32 such casemate towers around Linz in 1818 – 1836 (Hoyer, 1819; Zastrow, 1854, pp. 268–271). In 1850 – 1853, such Maximilian Tower was erected in Lviv on Kalicha Hora, which cost 150,000 of Roman gold (it has been preserved in the Lviv Citadel to this day).

The French divisional general Francois Nicolas Benoit Haxault (1774 – 1838), a participant in the siege of Antwerp (1832) and Zaragoza, in 1815 – 1830 built a belt of

19 fortifications with 10 forts at the distance of 600–800 m (i.e. effective artillery fire) from each other, abandoning a solid fortress fence. The Haxo casemate was built with a thick soil embankment, which absorbed the impacts of projectiles of vertical, direct and ricochet fire) (Truttman, 2000).

The main defense was in ditches, fortified with brick walls-escarpments and provided with *caponirs* placed at the bottom of a ditch or on the *glacis* at an angle to the ditch (oblique *caponir*). Ordinary caponiers provided fire in two flanking directions, and oblique – also along the front. Such a *polygonal front* provided a strong frontal defense and protected against *enfilade fire* (i.e. flank fire along the longest axis). In 1836 – 1851 the polygonal system largely replaced the bastion system (Bellamy, 1990). In the caponiers, light artillery was replaced by mitrailleuses, and from the end of the 19th century – machine guns.

The scientific and technical revolution, first of all appearance of steam engines and railway transport, called for the need for defense of bridges and development of special fortresses for their cover (*tete-de-pons*), which were transformed into main fortification complexes.

Defensive structures of the land front of Sevastopol, the construction of which began already after the landing of the allies and was carried out under difficult conditions without sufficient material support owing to a brilliant organizer, engineer-lieutenant colonel (in the future – an engineer-general) Eduard Johann von Tottleben (1818 – 1884), somewhat fall out of the general process of defense fortification evolution. E. Tottleben constructed the planned and erected new bastions from materials which were at hand, sometimes covering them with almost field engineering items during the defense – separate batteries, *redoubts* and *lunettes* adapted to the peculiarities of the terrain, as well as providing *mine galleries* against the enemy's attempts to blow up these fortifications. After the fall of Sevastopol, while dealing with fortifications of Mykolaiv, Major General E. Tottleben developed the idea of a system of forts as the main strongholds, with intermediate artillery positions, to which railway tracks were to be brought (Brialmont, 1884; Weigett, 1861; Werner & Werner, 2017; Horev, 1955; Zverev, 1956; Zurnal wojennych dejstwij, 2010; Zurnal wojennych dejstwij, 2016; Lagowski, 1939; Lampert, 1990; Oettingen, 1894, pp. 403–408; Rieger, 1885, pp. 68–75; Skrickij, 2006, pp. 258–303; Stade, 1869; Tarle, 1943; Schilder, 2020).

In European fortification, the first evolutionary period of 1850 – 1870 was spent in discussions and attempts to introduce the Haxo system, i.e. the rejection of fortress fences in favour of a belt of individual forts located at the distance of 600–800 m from each other. A vivid example was the belt of forts in Lyon built by Hubert Rio de Fleury (1779 – 1866) in 1854, in which there were used the Haxo casemates.

In 1870 – 1880, while there were tests of rifled guns, which provided a greater accuracy and penetrating ability of projectiles, to which rifles gave a greater stability in flight, huge 10-inch (254-mm) guns began to be installed in forts. Initially, breech-loading models won the competition with muzzle-loading models, but at the end of the period, the first ones ousted muzzle-loading models equipment (Parkes, 1973, pp. 54–62). Fortification began again with filling the gaps between forts with installation of separate batteries (Velichko, 1922, pp. 8–9).

The following period of 1880 – 1886 was characterized by the placement of the outer line of forts on higher ground levels of 5–8 km from the core of the fortress. Fortifications were built of brick and natural stone with soil filling to reduce the force of a shot. Using tethered aerostats and airplanes, the enemy could easily detect the placement of batteries and fire shrapnel at their stationary positions on *barbets* (open areas). Therefore, *poterne*-caves, which previously served for personnel shelter and preservation of ammunition, began to be

used for placement of guns. In such *poterne*-caves with the length of 20–25 m, the width of 230–240 cm, the height of 220–230 cm with a rounded vault, connected to each other by transitions, it was possible to roll guns in case of fire (track width 1610 mm), and close the entrance with a wooden shield that protected against shrapnel. This kind of protection for fortress batteries was considered the most promising (Brunner, 1909; Velichko, 1910, pp. 46–47; Mondésir, 1909; Olejnikov, 2017; Staveshagen, 1910).

In 1886–1899 a new turn in fortification evolution was caused by the appearance of fougasse, high-explosive (from *fougasse* – force of impact into the obstacle) bombs (bombes torpilles), filled with a large amount of explosive substance, which, upon impact, blew away brick or stone masonry along with eathern covering. Since 1899, the era of concrete and later reinforced concrete fortifications began (Velichko, 1922, pp. 9–10).

During this period, the Belgian engineer Henri Alexis Brialmont (1821 – 1903) made speeches in the military press actively, advocating for armored tower observation points and rotating gun turrets that could be made. He managed to implement his ideas in the fortifications of Antwerp, Liège and Namur, and later in the Chataljin Line in European part of Turkey and, partially, in Romania (Brialmont, 1863; Brialmont, 1885; Brialmont, 2010). The installation of armored towers spread rapidly in Germany and, partly, in France. The others treated this innovation quite cautiously, the Russian engineers led by K. Velichko opposed armored towers strongly (Velichko, 1887; Velichko, 1888; Velichko, 1890; Velichko, 1892).

The period of years of 1899 – 1914 marked the last stage of the evolution of a long-term fortification before World War I. This was the period of construction of powerful concrete and reinforced concrete forts (solid concrete on channels at least 11 feet (335.28 cm) thick with lateral retaining walls with stone covering and solid foundation retaining walls not less than 6 feet (182.88 cm) thick; at the end of the 19th century, brick and stone masonry began to be reinforced with layers of sand and concrete layers of 1 – 2 m) with armored rotary towers located on higher ground levels, underground galleries with electric lighting, water supply and ventilation, which received a new impetus after the use of poisonous gases by the Germans. Two-story concrete barracks with kitchens, bakeries, showers, operating rooms, tanks and cisterns, as well as central heating machines were installed (Velichko, 1922, p. 64). The space between forts was covered by wire fences and field fortifications. K. Velichko, the leader of the Russian fortifiers, advocated strong strongholds (forts-redoubts, in fact caponiers for fortress artillery), which were to be covered from the front by infantry field positions, emphasizing the need for flanking gaps and wire fences (Velichko, 1922, pp. 13–29). The Germans came to similar ideas as early as during World War I. The French took a more measured position, using the latest achievements of the German, Belgian and Russian schools of fortification. The Austrians were not fond of armored towers either, but they used the peculiarities of terrain and outer slopes of hills much better than the others.

The latter was facilitated by the introduction of firing practice from closed artillery positions (Tkachuk, 2021, pp. 46–48). In 1882, the Russian artilleryman Colonel Carl Hook published the work “Closed Firing of Field Artillery”, in which he suggested using geometry of angles at target points, which could be in any direction relative to the target. The use of geometry of angles would make it possible to place artillery behind the slopes of the hills, hiding it from enemy observation. At that time, there was no azimuth instrument that would allow this to be done. But as early as in 1890, the German designers made a richtfläche (an open gun sight, fixed and aligned relative to the barrel, which rotated and was capable of measuring large angles). The first firing from closed positions was used by the British field artillery on October 26, 1899 during the Boer War, and later

during the Russo-Japanese War of 1904 – 1905, both sides used such firing using rangefinders and panoramas and telephone communication. From 1908, the Russian artillery began to use the new German Hertz panoramic sight, which had graduations with a five-minute interval in decidegrees and mils (4320, 4000 or 6000/6300/6400 to circle). In 1908 – 1909, in maneuvers, the major European armies tested the effectiveness of firing from closed artillery positions using advanced observation posts connected with batteries by field telephones. In the course of these checks, it became clear the need to change the positions of artillery batteries quickly in order to avoid the possibility of covering them with shrapnel fire. But not only field artillery batteries, but also stationary fortress batteries were to be placed not on the tops of hills, but on their opposite slopes. At the same time, casemates for placement of personnel and ammunition were arranged in bunkers built into slopes of these hills and reinforced with stone or brick masonry and covered with ground and concrete layers on top. Such batteries were connected with front command and observation points (COP) by an underground telephone cable, which increased reliability of communication significantly. The COP itself could be placed in well-disguised concrete or armored posts closer to the enemy. To cover such batteries, infantry positions with machine gun nests were deployed on the frontal slopes. One of the first fortresses that met the latest requirements for the use of firing from closed artillery positions was the Austrian *tete-de-pons* of Mykolaiv, which covered the bridges across the Dniester (Voitovych, 2022, pp. 18–42).

In 1772, having received Galicia after the first division of *Rzech Pospolita*, which became part of the Habsburg Empire as the Kingdom of Galicia and Lodomeria, Austria had to solve the problem of defending this flat territory with small rivers. The best of the Austrian generals of the 19th century, Field Marshal Count Joseph Radetsky's opinion (1766 – 1858) was the following: due to the lack of natural boundaries, it makes no sense to defend the territory of the Kingdom of Galicia and Lodomeria and its capital, Lviv. He suggested the idea of concentrating the army on the southern slopes of the Carpathians before the exits from the mountain valleys, covering the Danube basin and relying on long-term fortifications, which would allow to stop the enemy for a certain period of time and focus on necessary directions of the forces superiority (Radetzky, 1858, pp. 423–451). Field Marshal Archduke Johann von Habsburg (1782 – 1859) suggested the idea of building a fortress in Przemyśl (Schlosser, 1981, pp. 281–305), and the above mentioned leading Austrian fortifier Major General Archduke Maximilian von Habsburg-d'Este suggested building fortifications in Lviv and Stryi (Hilbrand, 1975, p. 168). A heated debate among the Austrian military authorities regarding the defense of Galicia continued until 1850, when the Central Fortification Commission, chaired by *Feldzeichmeister* Heinrich Hermann von Hess (1788 – 1870) (a former chief of staff in the Italian Army of Field Marshal Radetsky, an authoritative general, later a field marshal) (Wurzbach & die Freiherr von, 1862, pp. 415–423) accepted a compromise option on the forward line of defense along the Dniester with the construction of flanking fortresses in Kraków, Przemyśl, and Załuszczyky and an intermediate *tete-de-pons* (a bridgehead fortification) in Rozvadów near Mykolaiv. Lviv was located a 3–4 day walk from the border, that is why, it was considered as an auxiliary point of fortifications between the Sian and the Dniester. Except of the citadel, the construction of which began in 1849, no new fortifications were planned there (Djedyk, 2013, pp. 20–30). Work on the construction of fortifications was stopped at the beginning of April of 1856 after signing the Peace of Paris.

In 1874, *Feldzeichmeister* Franz von Jon (20.11.1815 – 25.05.1876), Minister for Military Affairs (1867 – 1868) and Chief of the General Staff (1869 – 1875), rejected the idea of defense in Prykarpattia at all, suggesting the idea of using this territory as a springboard for an offensive.

In the autumn of 1877, the idea of an offensive from the Carpathian bridgehead was supported by the next Chief of the General Staff, Field Marshal-Lieutenant Anton von Schönfeld in the suggested war plan against Russia, predicting the success of such offensive due to a faster deployment of mobilization, which was facilitated by the constructed network of railways (Djedyk, 2013, pp. 27–28). But there were numerous cavalry units at the disposal of the Russian command, first of all the Cossacks, who with their raids could nullify the Austrian advantage in deployment at the expense of the railway network, destroying bridges and stations. Taking into account the experience of the British in protecting railway stations during the Anglo-Boer War of 1898 – 1902, there were developed projects of typical blockhouses to protect railway stations and tunnels with walls up to 50 cm thick, designed to protect against carbines and machine guns fire that were in service with the Russian cavalry (Baczkowski, 2002, pp. 111–122; Bogdanowski, 1966, pp. 72–96; Suchoń, 2009, pp. 51–59; Suchoń & Olesiak, 2019, pp. 89–107).

Russia spared no money to spread its influence on the Slavic population of Austria-Hungary, supporting various Slavophile currents, especially among the Galician Ukrainians, who called themselves *the Ruthenians* and supported the Russophile direction. Gradually, these currents transformed into open muscophilism. The leaders of the Muscophiles were priests who had a significant influence on the rural and bourgeois elite, therefore, the Russian intelligence found confidants among this elite easily and received sufficiently detailed information about the construction and condition of fortifications on the territory of Eastern Galicia (Hajsenjuk, 2017, pp. 90–149; Sukhyj, 2003). The Russian intelligence managed to force the head of counterintelligence of the Austrian General Staff, Colonel Alfred Redl (1864 – 1913), to work for it, taking advantage of the latter's fascination with handsome young men. A. Redl photographed and gave the Russian intelligence the mobilization plan of the Austro-Hungarian Army (Plan "R"), as well as other documents, including the plans of the Galician fortresses (Voitovych, 2021, pp. 56–59; Markus, 1984; Mil'shtejn, 1966, pp. 47–56; Moritz & Leidinger, 2012; Rauchensteiner, 2003, pp. 244–245). Thus, the lieutenant colonel of the Russian General Staff, Count Serhiy Pototsky (1877 – 1954), relying on information from military intelligence, noted that the double tet-de-pon of Mykolaiv, having 27 fortifications along an eight-kilometer arc, was weaker in the right flank ("because the forest prevents from observation and shelling") (Potockij, 1911, p. 75). But in 1913 – 1914, the chief of the Austrian General Staff, General Franz Konrad von Getzendorff, managed to carry out a number of modernizations, in particular the construction of *Lysa hirka* fort (Tarandov) in the tete-de-pons of Mykolaiv, which the Russians discovered only during the hostilities in September of 1914 (Baczkowski, 2004, pp. 111–112). In new forts, firing from closed artillery positions was to be used, which was the latest innovation in Europe. They were covered by a three-row line of field fortifications, in the system of which there were three batteries of 8-cm (actually 76.5-mm) M.17 Guns made by the Skoda company with a firing range of 6.7-kilogramme grenades up to 7 km; machine gun nests; observation posts and dugouts connected by underground tunnels and communication passages. The majority of these objects were built of stone or had reinforced concrete floors, they were reinforced by ordinary earthen trenches (Juschenko, Petryk & Piniak, 2021, pp. 7–45).

The Conclusion. Thus, it can be stated that the evolution of European long-term fortification took place in 1850 – 1914 under the influence of rapid changes of the scientific and technical revolution, invention of steam engine and later – electric engine, development of railways and other factors. There was a complete rejection of the bastion and subsequent polygonal defense systems and rejection of solid fortress fence. New ideas for defense

construction and fundamental changes in fortification survived several short-lived but intense periods. In 1850 – 1870, a solid fortress fence was replaced by a belt of forts located at the distance of 600–800 m from each other. In 1870 – 1880, intermediate batteries appeared, the following period of 1880 – 1886 was characterized by the location of forts at the distance of 5–8 km from the core of the fortress with the use of poternes to protect both soldiers and objects under conditions of possible shrapnel attacks. In 1886 – 1899 the use of high-explosive bombs led to an intensive search of shelter, which culminated at the last stage in 1899 – 1914 in the appearance of concrete and reinforced concrete fortifications, armored rotary towers and other improvements, which were prompted by the introduction of firing from closed artillery positions. This evolution of a long-term fortification spread in all European countries, which soon converged on the battlefields of the world war. The war confirmed the importance of tete-de-pons, the importance of flanking wire fences and the space between fortifications, and the need to cover the forts and artillery positions with infantry field fortifications. Despite the use of 420-mm howitzers, the reinforced concrete forts of Verdun and other fortresses fulfilled their task, and the armored rotary towers on higher ground levels also demonstrated their feasibility, being used during subsequent periods of fortification development. In general, the study of a long-term fortification evolution in 1850 – 1914 needs further development using preserved plans of fortresses on various fronts and their defense materials, which have become more accessible in recent years.

Acknowledgement. We express our sincere gratitude to all members of the editorial board for consultations provided during the preparation of the article for publishing.

Funding. The authors did not receive any financial assistance for the research and publication of this scientific work.

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The article was received May 14, 2022.

Article recommended for publishing 23/11/2022.