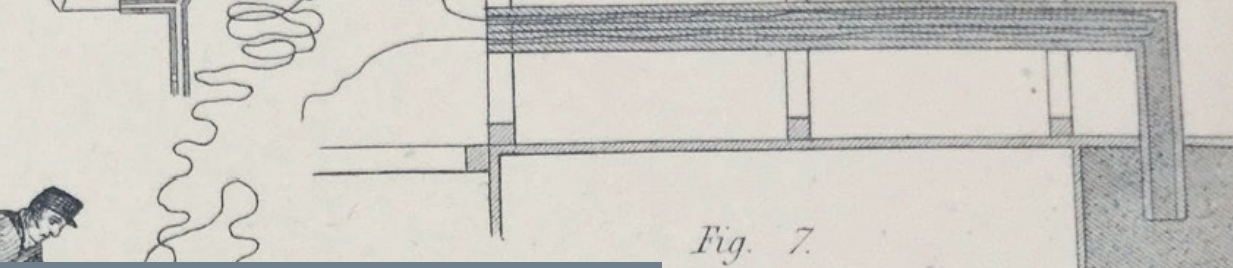
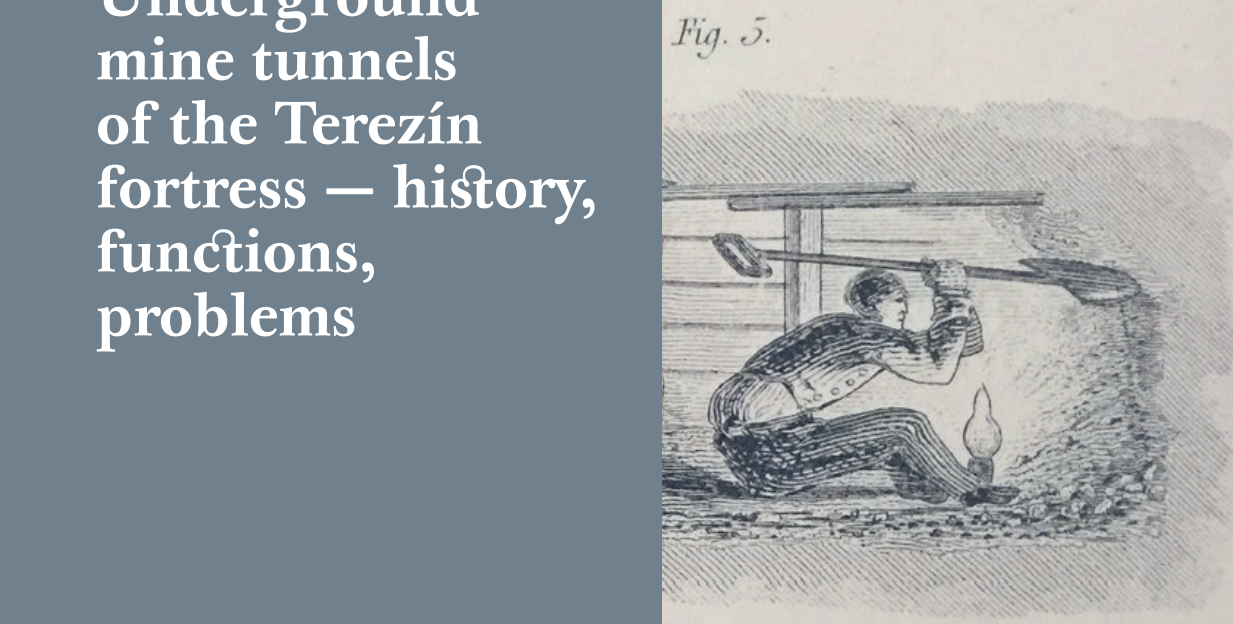
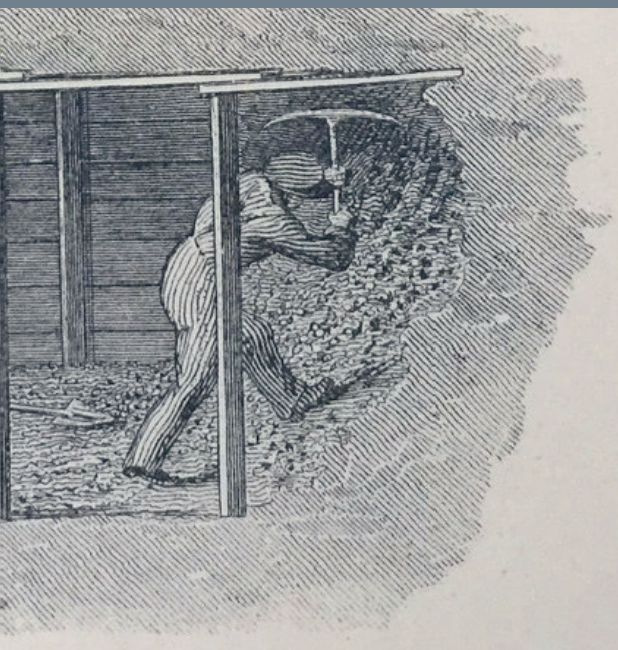
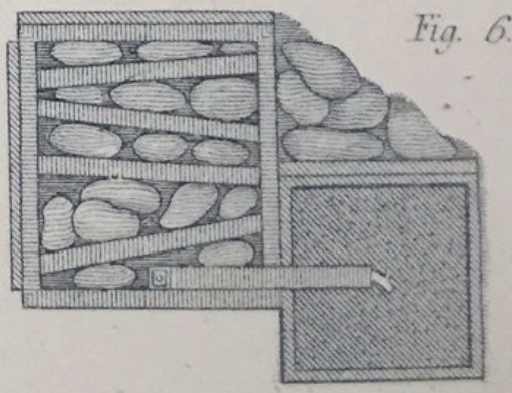
Underground mine tunnels of the Terezín fortress — history, functions, problems









Underground mine tunnels of the Terezín fortress — history, functions, problems

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Illustrative drawing depicting a reconstruction of the tunneling process (Author archive). →

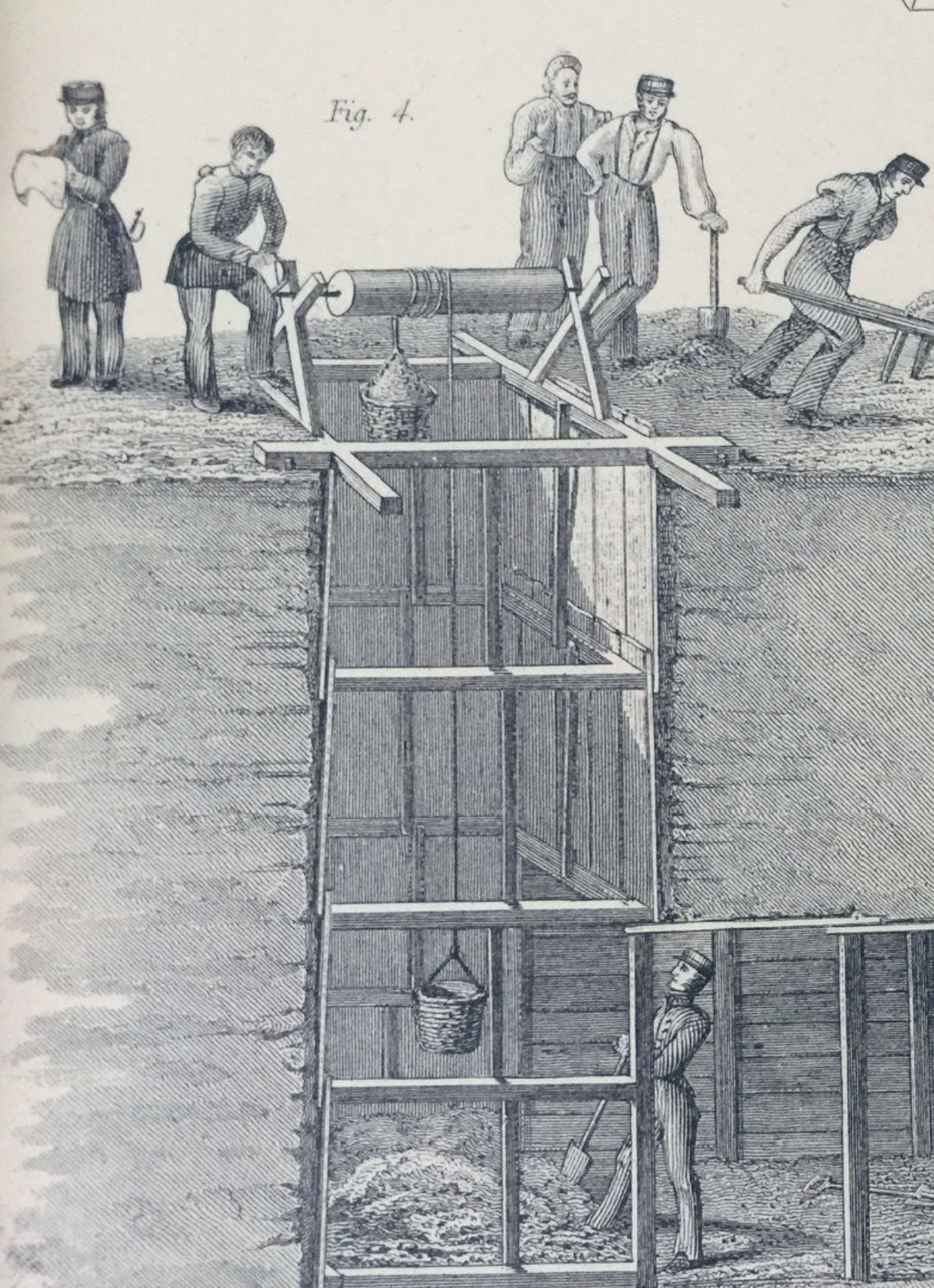


Fig. 4.

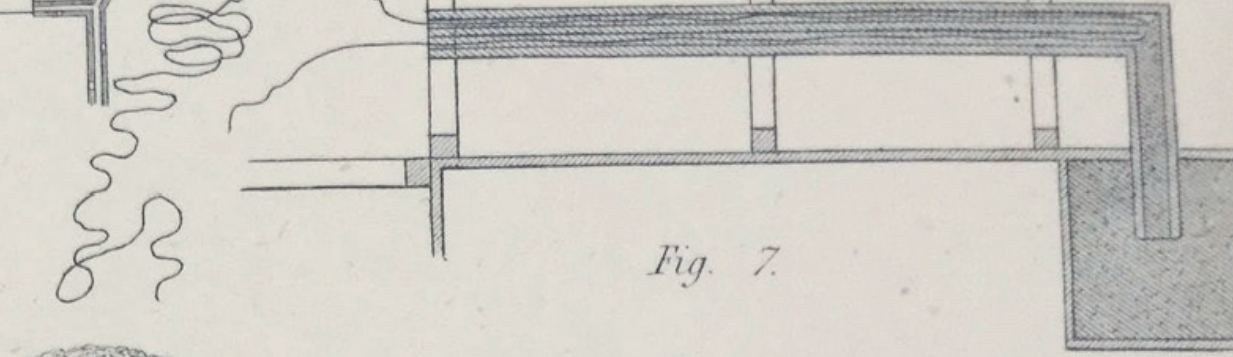


Fig. 7.

Fig. 5.

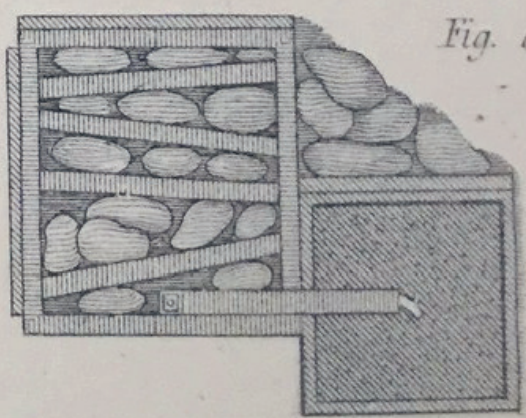


Fig. 6.

Introduction

When it became clear after the end of the Seven Years' War that the Habsburg Monarchy had lost part of the Lands of the Bohemian Crown — Silesia and Kłodzko, Maria Theresa began to refortify the northern border of Bohemia. At the time, a trio of modern, state-of-the-art fortresses for their time — in Hradec Králové, Josefov, Terezín (and further in Moravia, Olomouc) — were built as an addition to the somewhat outdated Prague and Cheb fortresses. They synthesized currently available European fortification trends and formed such elaborate defence systems that they are still unique cultural, architectural, and technical monuments today. It also includes an underground defense tunnel system.[1]

Mines and counter-mines[2] were not a new element in military technology in the 18th century, but they have always been used mostly by the besieger as underground passageways for tearing down or blowing up walls. It was not until the 18th century that counter-mines were used for defensive purposes. These ideas are primarily associated with names such as Vauban and especially Belidor, while the name Schröder resonated greatly in contemporary Austria.[3] At the end of this process, counter-mines became a significant defensive element of fortresses that managed to completely turn the technology of warfare around. As the architect of the Josefov Fortress, General Querlonde said a fortification without a counter-mine system cannot be defended.[4]

Underground warfare, called tunnel warfare in professional literature, was not unknown in the Central European area. It was largely defined by the legendary siege of the fortress of Svídnice in 1762 and the fortress

1 The latest literature on the construction of the Terezín fortress: Ivan FUKSA, *Pevnost Terezín – proti pruské rozpínavosti*, Prague 2016.; Jiří HOFMAN, *Paměti o obraně pevnosti Terezín – translation of the original written in French by Field Marshal Charles Clement, Count of Pellegrini*, Prague 2023.; SAME, *Vlasti k obraně, matce ke cti – Stavba pevnosti Terezín 1780-1790*, České Budějovice 2022.; Vladimír KUPKA et al., *Pevnost Terezín*, Prague 2010.; Andrej ROMAŇÁK, *Pevnost Terezín*, Dvůr Králové 1994.; SAME, *Pevnost Terezín a její místo v dějinách fortifikačního stavitelství*, Prague 1972.

2 In contemporary terminology, a mine is used by the besieger to destroy the defender's positions, and a counter-mine is used by the defender to destroy the besieger.

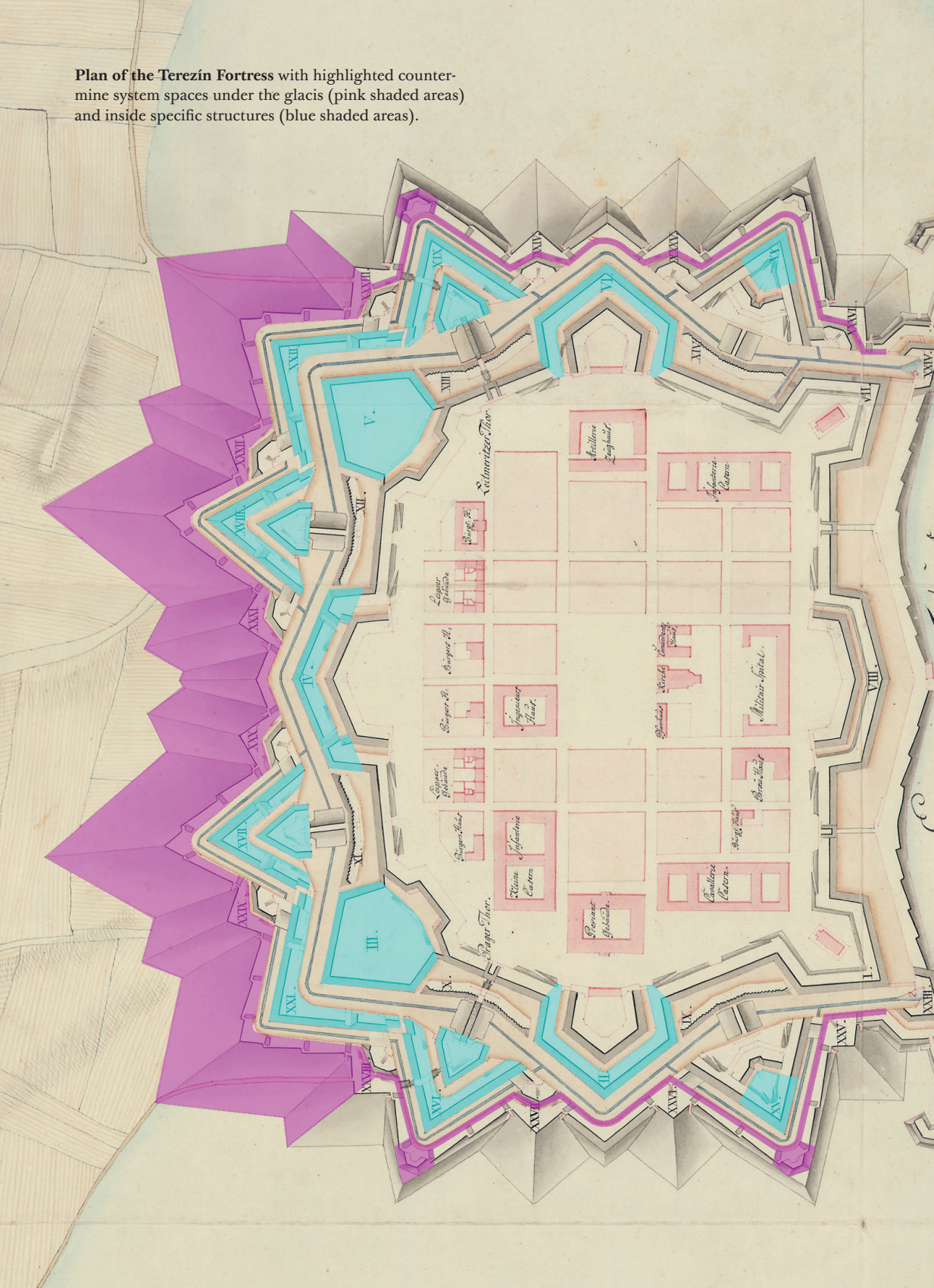
3 Maximilian de TRAUX, *Die beständige Befestigungskunst*, Wien 1817, s. 453.

4 Österreichisches Staatsarchiv, Kriegsarchiv (dále jen KA), Karten – und Plansammlung, Karten und Plansammlung – Landesbeschreibung K VII c, 74-3 F, Memoires der Festung Josephstadt von Generalmajor Quelronde, s. 23.

of Bergen op Zoom in 1747. Both the besiegers and the defenders found that a well-used mine system could slow down or even stop an attacker for several weeks.[5] New imperial fortresses had to be equipped with a mine system, if technically possible. And Terezín was one of them. It was here that suitable terrain conditions allowed Austrian engineers and miners to design what they considered to be the 'perfect' system, which has survived to this day.

[5] On both sieges:
Petr WOHLMUTH, *Krev, čest a hrůza: Historická antropologie pevnostní války na příkladu britských deníků z obléhání pevnosti Bergen op Zoom z roku 1747*, Praha 2017.; Johann Georg TIELKE, *Die drey Belagerungen und Loudonische Ersteigung der Festung Schweidnitz in den Feldzügen von 1757 bis 1762*, Freiberg 1781.

Plan of the Terezín Fortress with highlighted countermine system spaces under the glacis (pink shaded areas) and inside specific structures (blue shaded areas).

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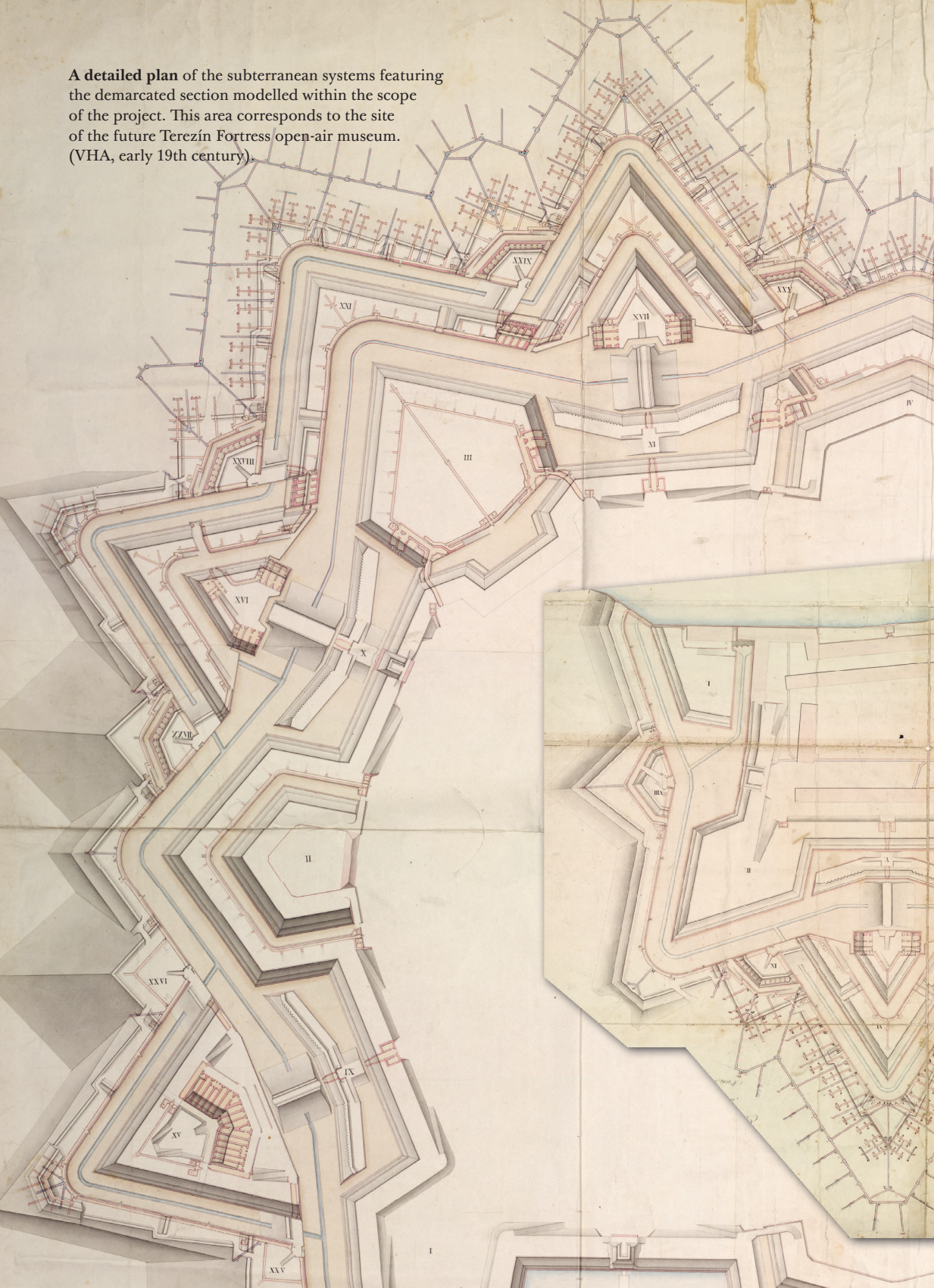

A detailed plan of the subterranean systems featuring the demarcated section modelled within the scope of the project. This area corresponds to the site of the future Terezín Fortress open-air museum. (VHA, early 19th century).


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Description of the system

Like the entire Terezín fortress, its underground system is systematic, symmetrical and defined by the overall layout of the fortifications. Both the Main Fortress and the Small Fortress have their own system — in the terminology of the time, '*fortress*' and '*fort*'.[6] The intermediate space between the retrenchments and the sides adjacent to the new or old Ohře riverbed did not contain them. The north and south sides are protected by a large floodplain with only a simple system of mines. The most extensive and most elaborate complex of underground mines is located on the western side of the Main Fortress between the floodplains, where the terrain is above any possible floodwaters. The same applies to the tunnels of the Small Fortress, only in reverse on the east side. Let's take a closer look at its description. Since the terminology of the permanent counter-mine system in Terezín, as the official term goes, varies in literature, we will use the original names from written sources and planning documents.[7] These also match various manuals and textbooks from before and after the construction of the Terezín fortress.[8] We leave the original technical terms in German or French in parentheses. The metric system is used for the dimensions, converted from historical plans. If they are included in the cited texts, we keep them as they were and list the current measurements in parentheses.

The **main gallery** (e.g. '*Kontraeskarpe-Galerie*', also '*Galerie Majeure*', or '*Mordgang*') that leads around the entire fortress from the inlet to the outlet sluices, except for the waterfront side, is a fundamental element of the mine system.[9] Its brick floor runs about 130 cm above the bottom of the

6 For terminology, cf. J. HOFMAN, *Paměti o obraně pevnosti Terezín*.

7 The greatest number of contemporary sources can be found in the following collections: KA, Mittelbehörden, Geniewesen, Geniehauptamt, Akten.; Ibid., Zentralstellen, Wiener Hofkriegsrat, Hauptreihe (1557-1848), box 1282-1844.; Ibid., Karten – und Plansammlung, Genie – und Planarchiv, Inland C IV, Theresienstat (dále jen GPA Theresienstadt); Military Historical Archive Prague, Plans Collection of fortress Terezín and other military facilities in Terezín and around 1780 – 1943 (hereinafter Plans Collection Terezín).; Ibid., AF Engineering Directorate Terezín / Geniedirektion Theresienstadt (hereinafter GD Terezín).

8 Nejvíce M. de TRAUX, *Die beständige Befestigungskunst*.; ANONYM, *Abhandlung über die Befestigungskunst*, Wien 1795. Jean d'ARNAL, *Nouvelle méthode d'instruction sur la fortification, l'attaque et la défense des places pour les eléves de l'Academie militaire I[mpériale] et R[oyale] du Génie*, Vienne 1773 [online]. Available at: https://www.manuscriptorium.com/apis/resolver-api/cs/catalog/default/detail/manuscriptorium%7CAIPDIG-VHUP___IIR_F_391____335LM5B-cs [cit. 2024-12-6].

9 M. de TRAUX, *Die beständige Befestigungskunst,* pg. 460.

fortress ditches so that it can remain dry even when they flood. According to the documentation, the main gallery was built in such a way that its arching was based on the vertical alignment of the original terrain morphology, which facilitated construction, but more on that later. The tunnel is 130 cm wide and 195 cm high in its standard profile. It can be accessed either from the lunettes, places-of-arms or trenches. In the circular sections in front of the capitals of individual structures, the tunnel widens. Towards the trench, it contains niches with infantry loopholes and their ventilation holes leading under the cornice of the counterscarp masonry at regular intervals. These are recessed into the masonry at 48.7 cm, with a width of 151.6 cm. Each niche is 65 cm apart, allowing movement between sections of the covered way, even if the enemy has occupied certain sections on the surface. The loopholes were not just used to defend the fortress, the openings also brought fresh air underground and illuminated the main gallery.

On the outside, other tunnels extend into the forefield, or **walled-in niches** are prepared here, i.e. *blind fields ('Blindfelder'), enabling advancement against the enemy everywhere*. These make it easy to advance from the gallery through a new tunnel towards the enemy.

Before the protruding angles of the covered way and places-of-arms, the main gallery is equipped with a brick **traverse** with a door, infantry loopholes and holes for throwing grenades to enable defense against an enemy that has penetrated the tunnels. They would usually attack against the protruding angles of the fortification.

The bend at the protruding angles of the covered way is referred to as a **casemate** ('*Cassematte'*); it is more spacious and its layout allows for shooting at trenches along the entire length. The loopholes are not in niches, but on the face of the wall, which is thicker here.[10]

In the main gallery, at the primary entrances to the underground, are all the **hand depots** (e.g. '*Hand-Pulver-Magazins'* or '*Depots'*), which keep gunpowder, sandbags, tools and other necessary materials at hand.

From the main gallery towards the front line, there is a counter-mine system, consisting of mine branches, small galleries (e.g. '*Rameaux')*, which lead to chambers where charges were placed, or allow the defenders' miners to dig towards the enemy. In Terezín, there are two floors that alternate in a regular pattern. Up towards the surface are **level 1 mine branches** (e.g. '*Rameaux 1. Laage*') which are 81.2 cm wide and 130 cm high, followed by a smaller profile that is 65 cm wide and 97.5 cm high.

[10] J. HOFMAN, *Paměti o obraně pevnosti Terezín, pg.* 77.

Perspective view of the main gallery.
(J. Formánková Hofmanová).

At the level of the main gallery, the **level 2 mine branches** (e.g. *'Rameaux 2. Laage'*) extend into the forefield, which are 81.2 cm wide and 162.5 cm high along the entire length of the profile. These are also sloped slightly towards the side of the trench to ensure drainage of seeping moisture. All these tunnels naturally contain the aforementioned niches and, in appropriate sections, also grooves (e.g. '*Coulisses*').

The counter-mine system is minimised on the floodplain side, especially at the protruding angles of the covered way, because the main attack was not expected here. On the contrary, the western side is completely interwoven with them, as they were meant to provide the backbone of the defence at a certain stage of the siege.

The **upper galleries** (e.g. '*Gallerie Superieur*') are specific types of tunnels. These run partly up the stairs from the main gallery, forming a sort of square circuit and then descending back into the main gallery.[11] It is primarily a connecting tunnel from which level 1 mine tunnel branches extend towards the forefield.

The level 1 mine branches in Terezín branch twice on both sides under the glacis in a 'T' shape (e.g. '*Rameau en T'*). These branches were always bent at a right angle. At each end, small niches, called **chambers** (e.g. '*Kammer*' or '*Chambre*'), were placed towards the front, where the mine charges themselves were to be stored. At their mouths, there are grooves in the masonry (e.g. '*Coulisses*') that facilitate the insertion of beams to seal the charge.

On the western side of the Main Fortress (or the eastern side of the Small Fortress), an **envelope** (e.g. '*Gallerie d'Enveloppe*') runs parallel to the main gallery. Its vertical alignment is lowered towards the main gallery and is approximately 650-812.5 cm deep below the top of the glacis (e.g. *'Crete du glacis'*). It is 178.7 cm high and 81.2 cm wide.

The intersecting angles of this corridor contain **retrenchments** (e.g. '*Abschnitte*', '*Tambours*' or '*Retranchements*'), which are spacious rooms with doors and a pair of traverses for defending the room. They are essentially fortified intersections between two directions of the envelope and the tunnel to the main gallery (connecting gallery, see below).

The envelope also contains small chambers at regular intervals called

[11] The only exceptions are its smaller versions in front of the rests on the western side of the fortress, where they extend not from the main gallery, but from the connecting gallery.

a **place-of-arms** (e.g. '*Places des Armes*', '*Retranchemments*'[12], '*Abschnitte*' or '*Waffenplätze*'). Their main goal is to defend the area if the enemy were to reach the envelope. This is why there was a pair of doors made of thick planks with lockable loopholes.[13] However, these doors (as in the retrenchments) were not permanently located underground, but to prevent them from rotting, they were stored outside in a storage area during peacetime.[14]

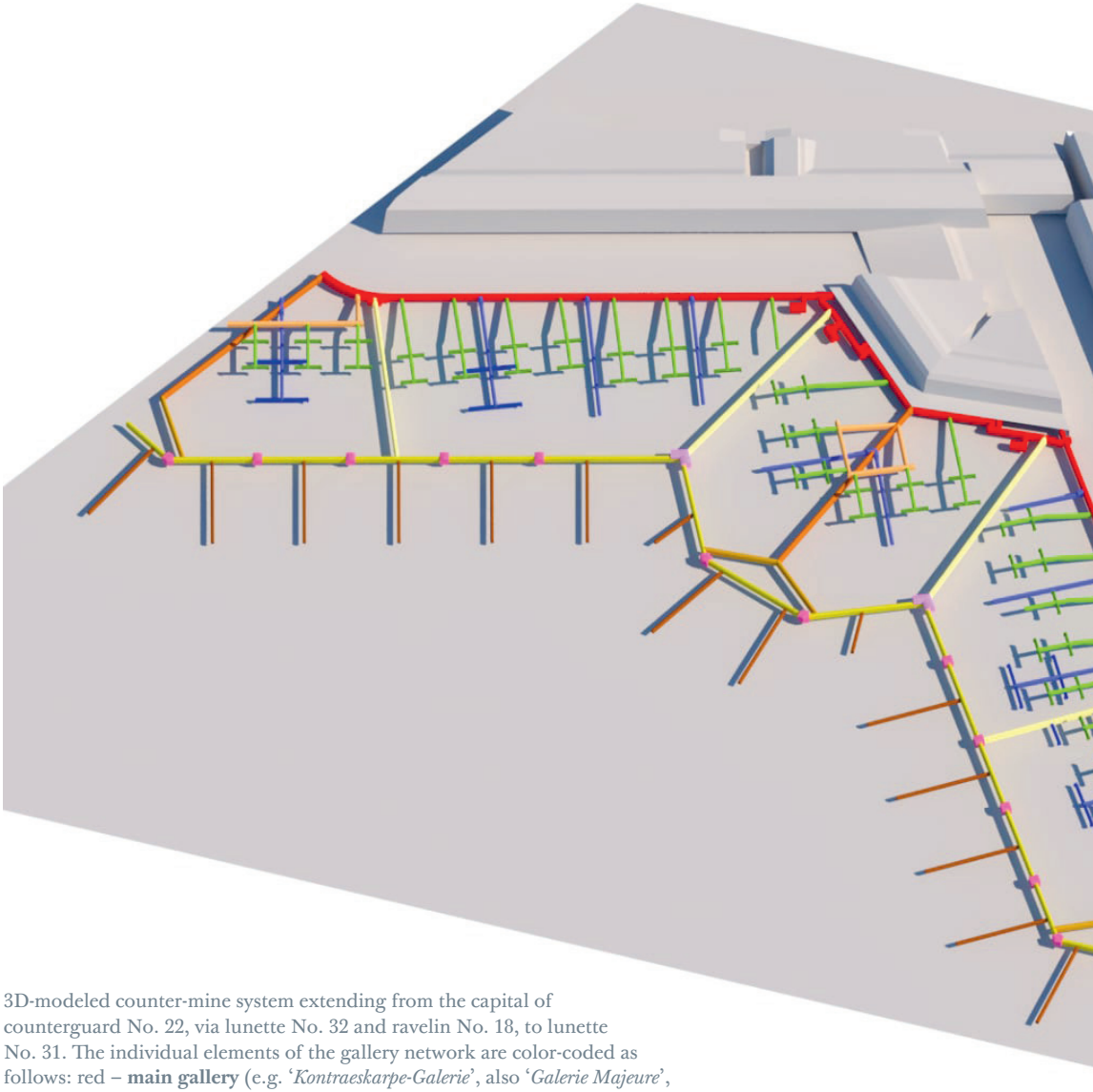
Listening galleries (e.g. '*Horch-Gallerien*' or '*Galerie d´écoute*') extend like antennae perpendicularly from the envelope into the forefield at regular maximum spacings of 23.4 m. They are 162.5 cm high and 81.2 cm wide, and like the entire envelope, they are equipped with niches for future tunnels. Their length varies depending on the time of their construction**.**

The main gallery and the envelope are connected by **communication galleries** (e.g. *Kommunikations-Galerien* or '*Galeries de communications*'). The dimensions are identical to those of the level 2 branches, because they are not just meant to be communication branches, they are also a part of the defense system. They are primarily located in front of the protruding angles of the covered way (3 tunnels) and in front of the place-of-arms (3 tunnels). Depending on the length of each section, communication galleries could also be added to these groups. If they pass through the capitals, they are also called the **capital gallery** (e.g. '*Kapital-Galerie*' or '*Galerie Capitales'*). These capital galleries are slightly different from ordinary communication galleries. Almost all of them divide at the ends and form a '**fork**' (e.g. '*Gabel*'), which is further referred to as right and left. The upper gallery also extends from the capital galleries in front of place-of-arms No. 28 to No.33.

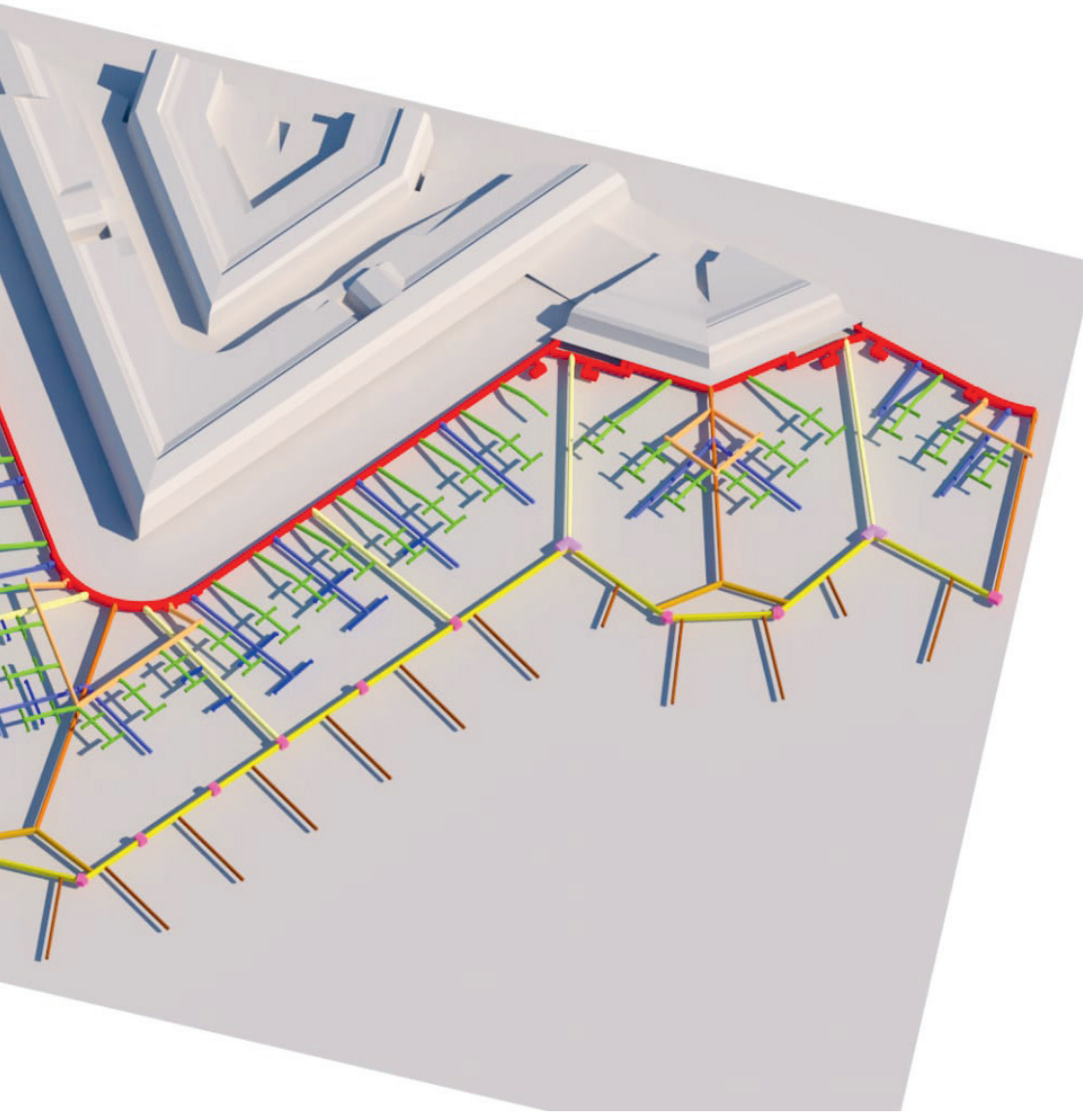
[12] The same term, sometimes denoting a place-of-arms, sometimes a retrenchment, and sometimes another fortification in different sources, shows the variability of fortress terminology. Link to the space above.

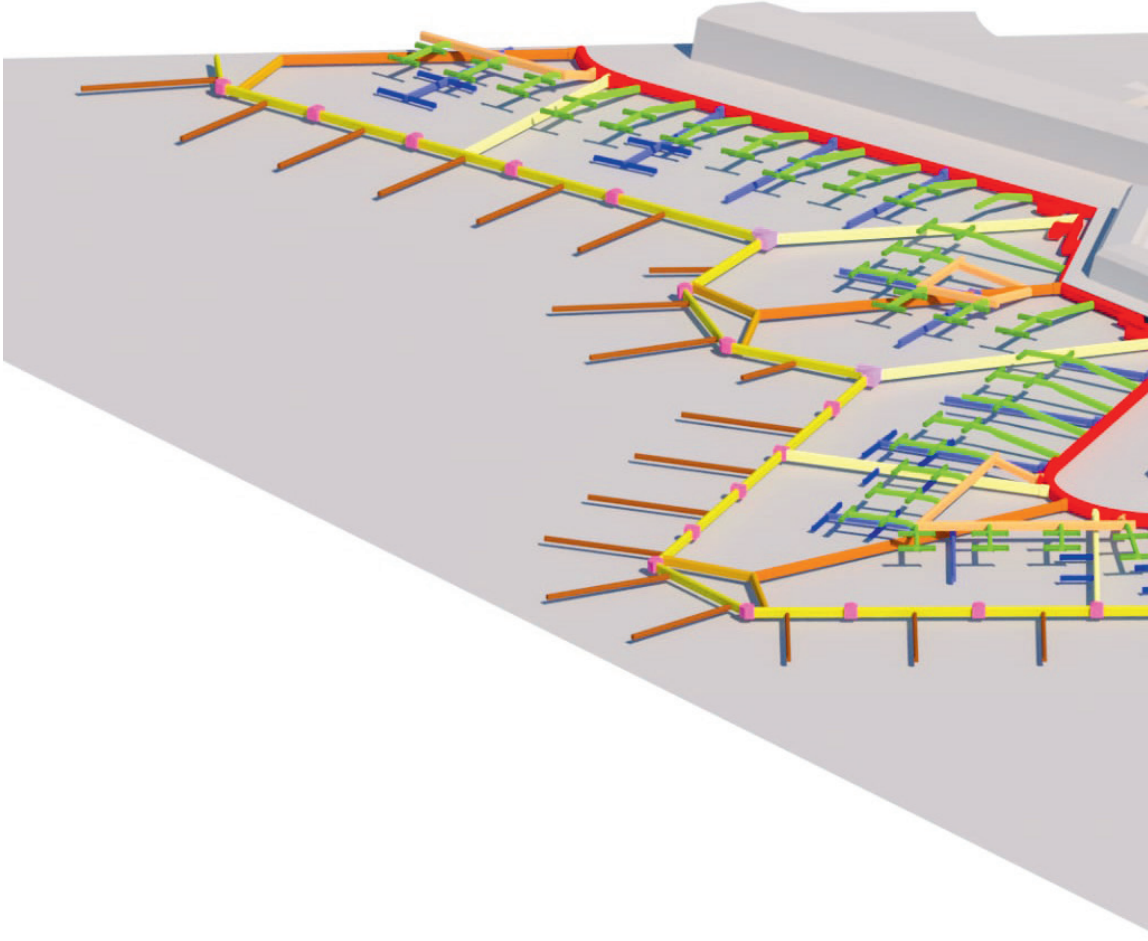
[13] Door plan, GD Terezín, box 10.

[14] GPA Theresienstadt Nr. 15, Gov. Eisenbach's report from 12 September 1866.



3D-modeled counter-mine system extending from the capital of counterguard No. 22, via lunette No. 32 and ravelin No. 18, to lunette No. 31. The individual elements of the gallery network are color-coded as follows: red – **main gallery** (e.g. '*Kontraeskarpe-Galerie*', also '*Galerie Majeure*', or '*Mordgang*') , including a casemate at the bend (orig. ‚Cassematte') and **hand depots** (e.g. '*Hand-Pulver-Magazins'* or '*Depots'*); orange – **capital gallery** (e.g. '*Kapital-Galerie*' or '*Galerie Capitales'*); light yellow – **communication galleries** (e.g. *Kommunikations-Galerien* or '*Galeries de communications*); ochre – '**fork**' (e.g. '*Gabel*'); light orange – upper gallery (orig. ‚Gallerie Superieur'); yellow – envelope (orig. ‚Gallerie d´Enveloppe'); brown – listening galleries (orig. ‚Horch-Gallerien' or ‚Galerie d´écoute'); pink – **retrenchments** (e.g. ‚*Abschnitte*', ‚*Tambours*' or ‚*Retranchements*'); blue – **level 1 mine branches** (e.g. ‚*Rameaux 1. Laage*'); green – **level 2 mine branches** (e.g. *'Rameaux 2. Laage'*).





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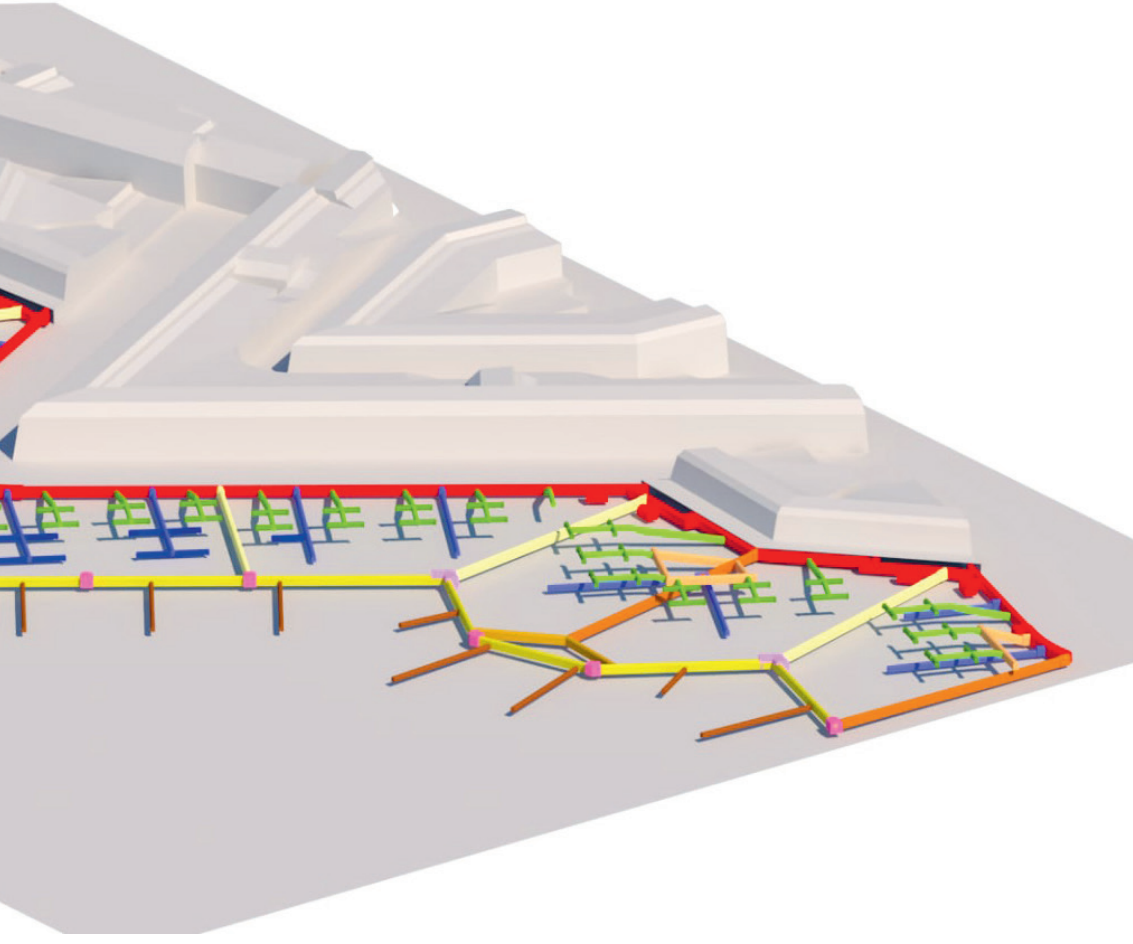

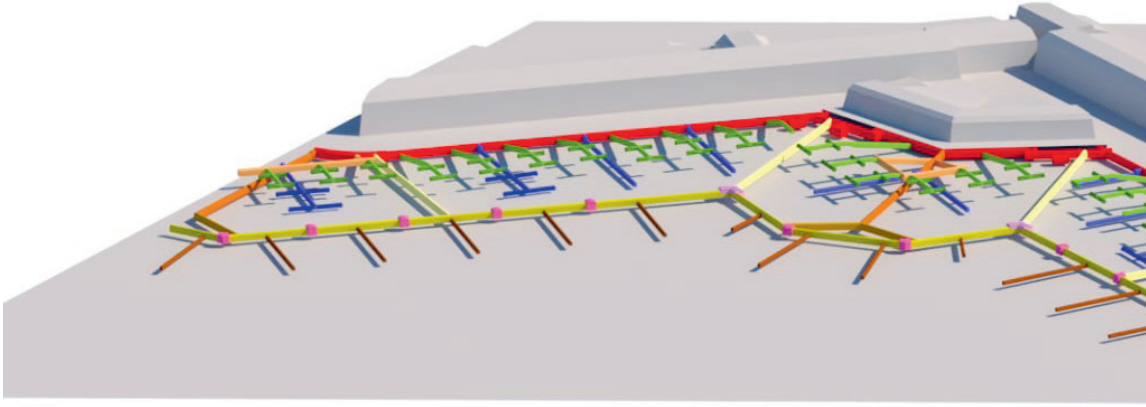

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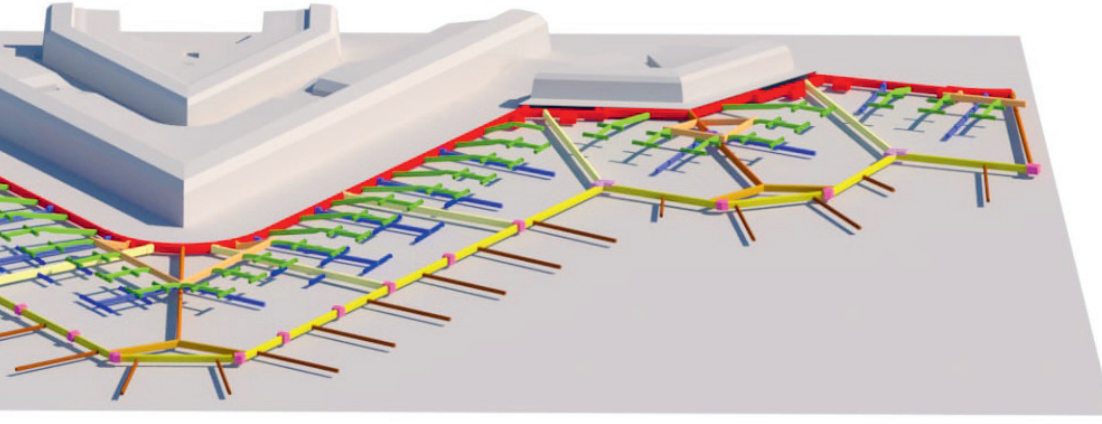

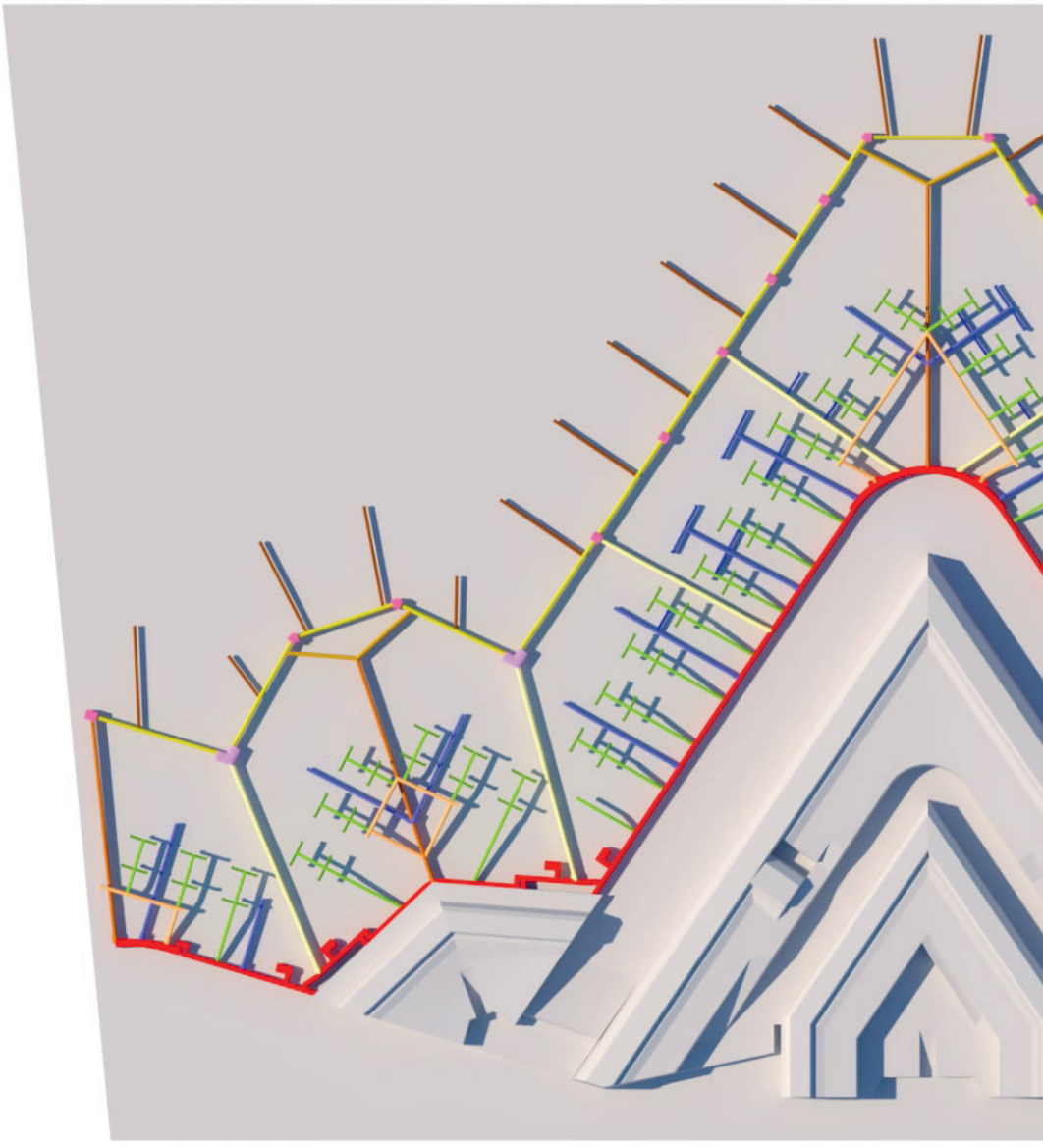

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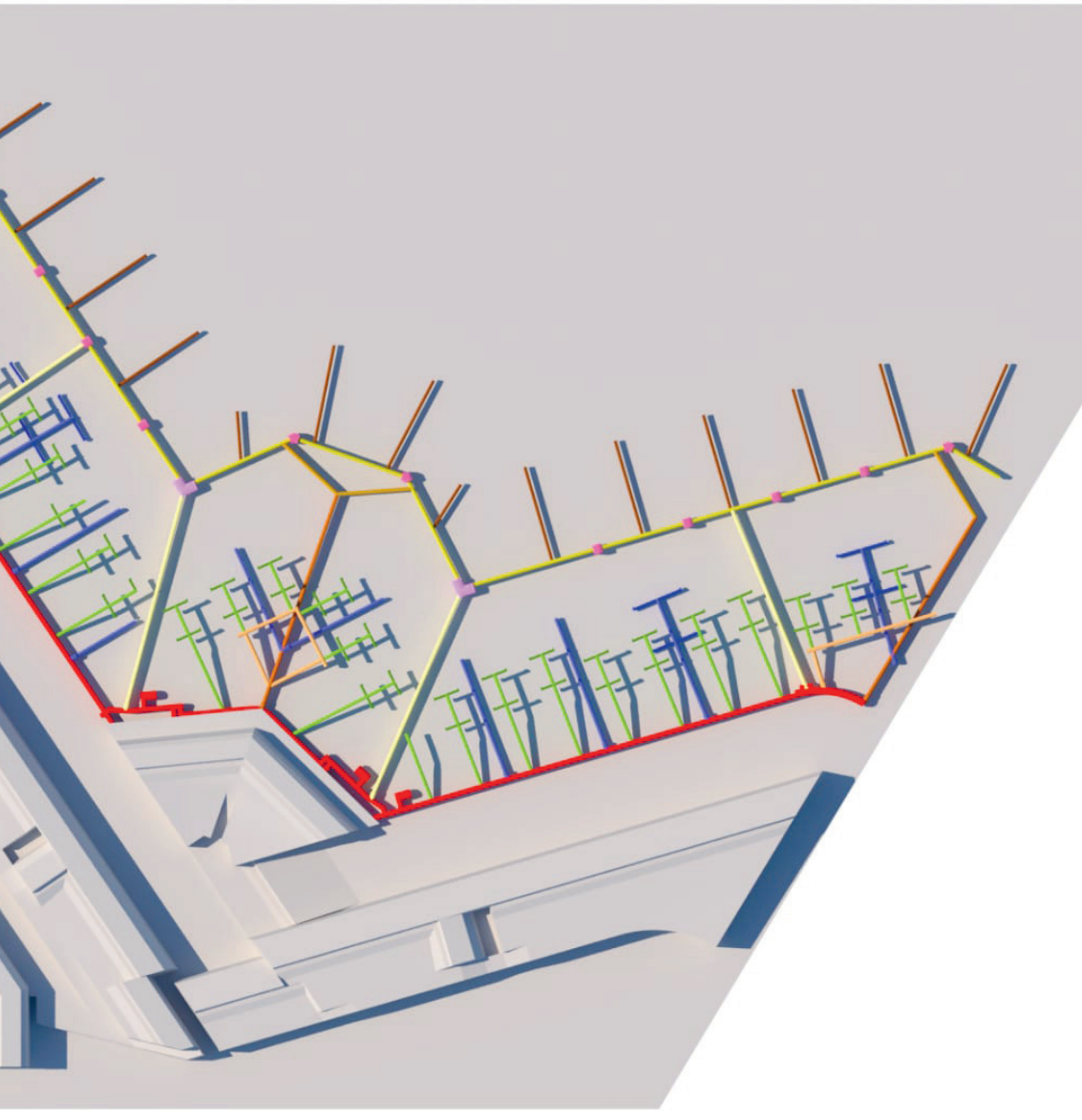


The number of individual structural elements of the mine system in Terezín is summarised in a table from 1805:[15]

Type of structure	Main fortress	Small fortress
Entrance to main gallery	56	24
Gunpowder storage	43	18
Upper gallery	15	7
Capital and communication gallery	31	11
Level 1 mine branches	152	74
Level 2 mine branches	74	35
Fork	8	2
Retrenchments on envelope	10	3
Place-of-arms on envelope	52	17
Listening gallery	70	23

The tunnels in individual fortress elements — bastions, ravelins, reduits, counterguards, etc. — are structured similarly to mines in the forefield of the fortress. Due to limited space, there is no envelope or related structures here. However, they generally contain a main gallery with mine branches, entrances, gunpowder storage areas and other spaces described above, which repeat regularly. Full bastions No. 3 and No. 5 also have a place-of-arms on the capital gallery, and ravelins No. 17 and No. 18 and the counterguards have a gun casemate in the arch of the trench. It is necessary to distinguish between other casemate spaces of these elements, which no longer fell into the numbering of mines — e.g. trenches, artillery casemates or shooting chambers in reduits, ravelins or bastions.

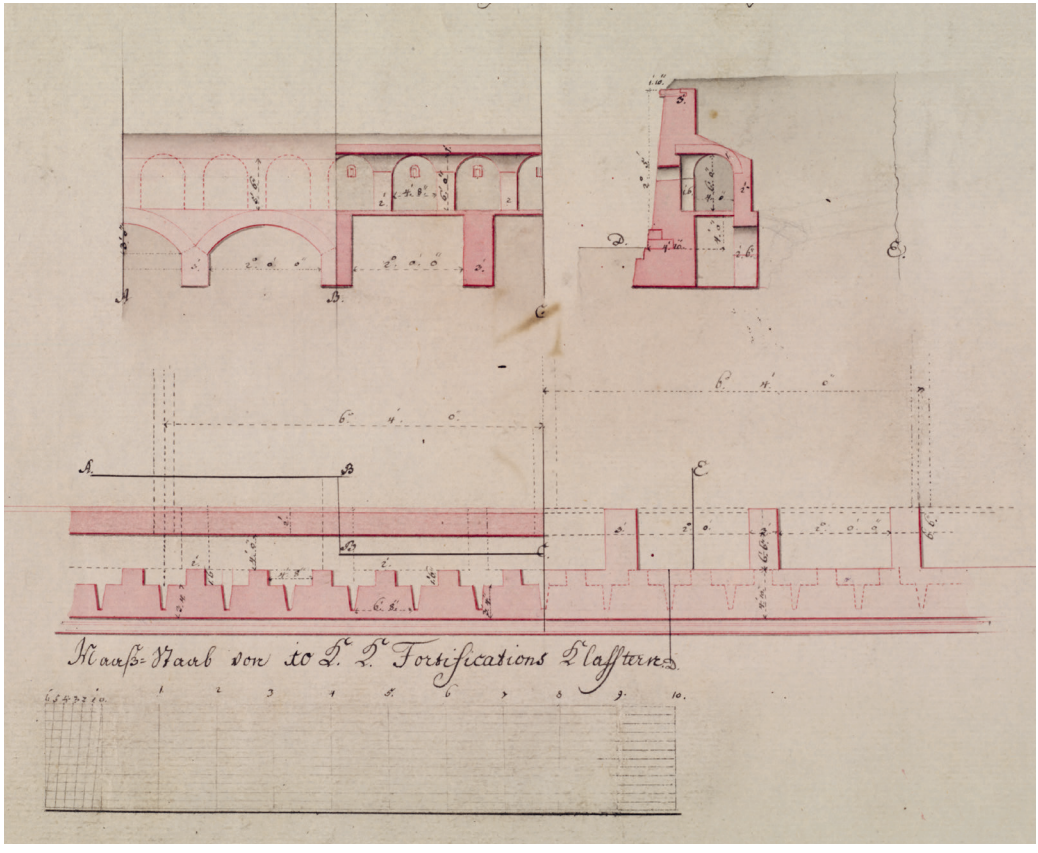
[15] Report of Gov. baron de Chastel, dated 6 June 1805 in Josefov, Plans Collection Terezín, III K 29.

Various historical phases of the markings for the entrance to **level 1 mine branches** No. 71. (J. Hofman).

Orientation in the above spaces was facilitated by the generally clear layout of the corridors and their numerical designation based on the above terminology. Essentially all underground structures have their own autonomous numbering — underground entrances, gunpowder depots, level 1 and 2 mine branches, traverses, listening galleries, places-of-arms, retrenchments. According to preserved inscriptions, the niches were also marked with numbers, and even doors to retrenchments and places-of-arms had their own numbers. E.g. '*Ram.1.L.71*' means level 1 mine branch number 71, '*Pld´a N. 40*' is place-of-arms number 40, etc.

Because all mines were originally (and to a large extent still are) plastered, way back the numbers were only drawn manually with ochre clay on the surface. A more recent method seems to be black inscriptions over a stencil, and the most recent method are probably metal plates, which have, however, not been preserved in their entirety.

Interior view of the casemate within the main gallery. (J. Formánková Hofmanová).



Design of the main gallery illustrating its cross-sectional profile, layout, and structural configuration. (VHA, undated).

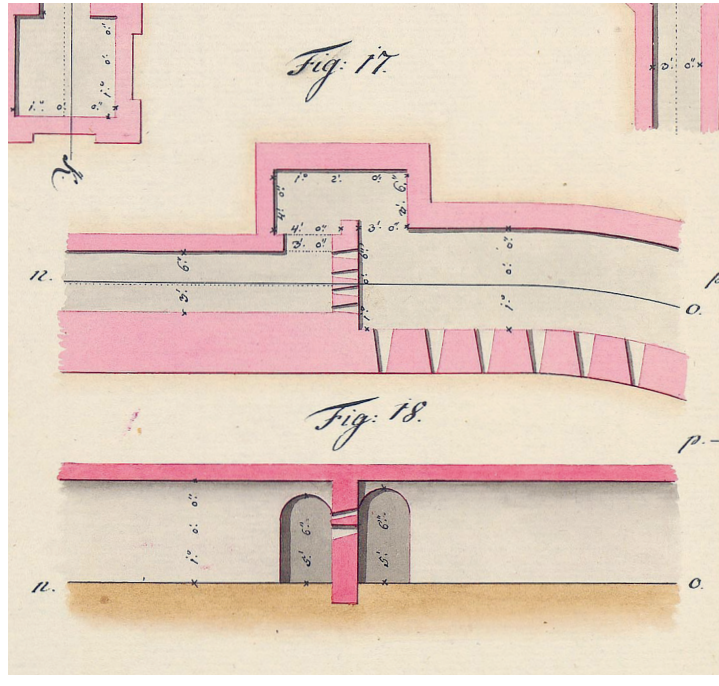
Rapport plan of the mine gallery system in the foreground of counterguard No. 21, illustrating the casemate configuration and its connections to additional galleries and traverses. (VHA, 1784).


Profil nach mn.
Profil nach der Linie PQ.
Profil nach der Linie EF.
Profil nach der Linie KL.
Profil nach der Linie IK.
Profil nach der Länge der Kleinen Gallerie magnum nach der Linie ABC.
Profil eines untern Raumes.
Profil eines obern Raumes.
Retranchement der Petite Pirmide N° XIX.

Main gallery entrances from the moat. (L. Hudák).

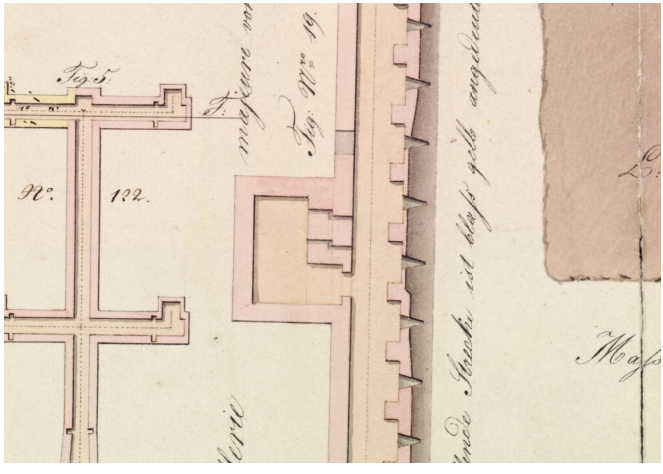
Main gallery entrances from the area
of the lunettes. (R. Gazsi).

Traverse within the main gallery, view from the casemate; to the right, the entrance to the upper gallery. (J. Formánková Hofmanová).



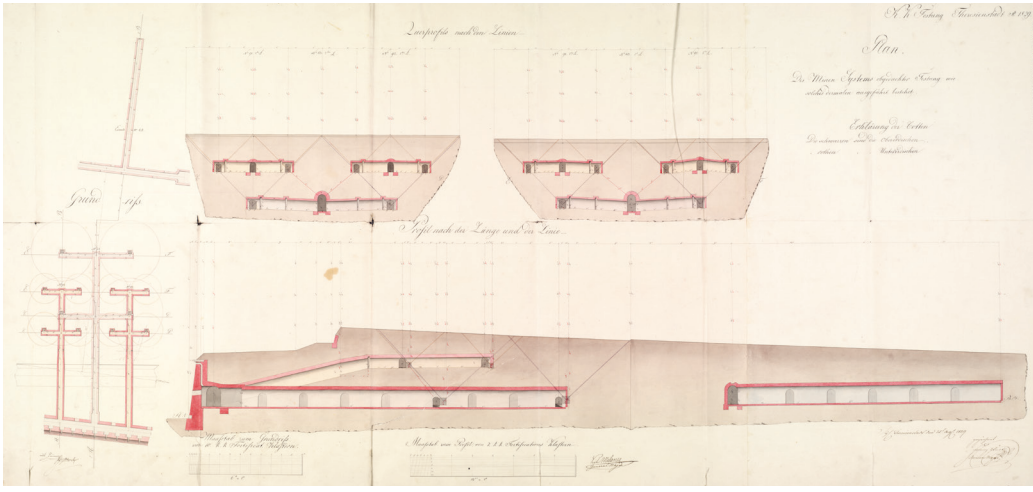
Contemporary plate illustrating various designs of tambours or places of arms with traverses (J. d'ARNAL, Nouvelle méthode d'instruction sur la fortification).

Photograph of a hand-powder magazine.
(R. Gazsi).

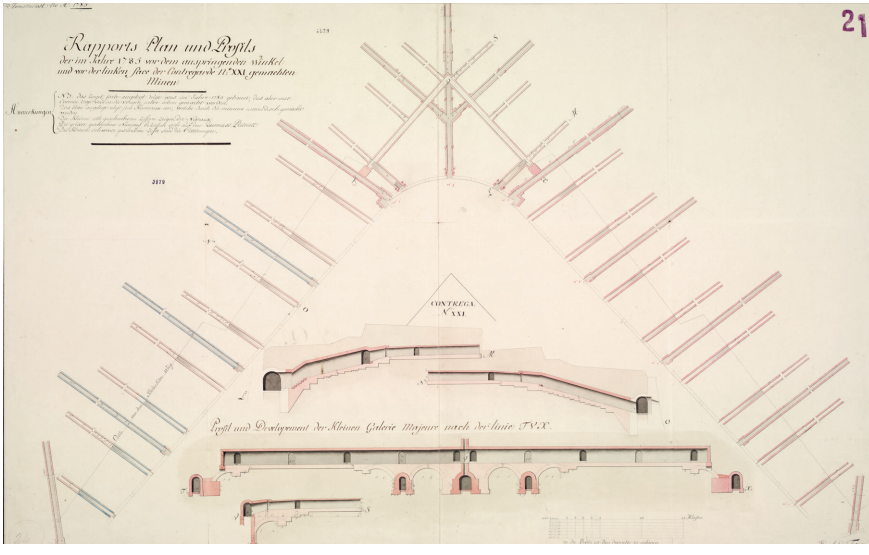


Technical drawing of a hand-powder magazine illustrating the ventilation system and door placement (VHA, detail from an 1829 plan).

Entrance to the upper gallery, the so-called Galerie Superieur. (R. Gazsi).



Plan of the expanded layout of the first and second-tier mine galleries, including the demarcated mine craters of projected detonations. (VHA, 1829).



Rapport plan of the upper gallery in the foreground of counterguard No. 21, dating to the construction year 1785 – galleries excavated using mining techniques are demarcated in blue (VHA).

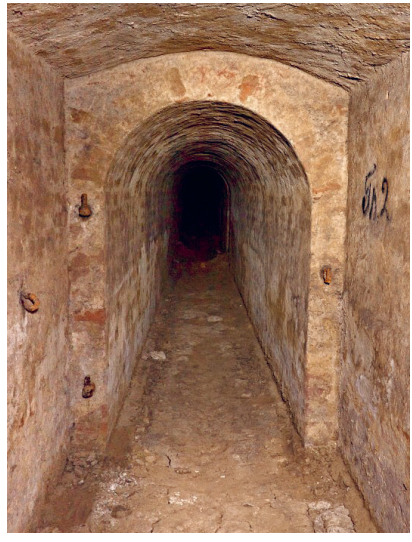
Interior view of the communication gallery featuring entrances to the upper gallery in front of the lunettes. (R. Gazsi).

Interior view of the envelope featuring walled-up niches on both sides. (R. Gazsi).

View of the inclined section of the **level 1 mine branches** featuring slots for timber beam insertion. (SPELEO – Řehák).

Interior view of the **level 1 mine branches** gallery at its face. (SPELEO – Řehák).

Interior view of the **level 1 mine branches** in front of the mouth of the mine chamber. (SPELEO – Řehák).



Interior view of the entrance to the **level 2 mine branches**. (SPELEO – Řehák).

Interior view of the tambours featuring traverses and entrances to the envelope. (R. Gazsi).

Capital communication gallery. (R. Gazsi).

Interior view of a place of arms on a straight section of the envelope. (L. Hudák).

Concept

It is not entirely clear who is the author of this oldest concept. The Terezín fortress is a joint project of the Habsburg engineering corps. Engineers and experts working on site, in Vienna and elsewhere designed individual parts.[16] We find the names of two miners — Mikowini[17] and Březina — in preserved sources.[18] But what was the fate of the Austrian mining corps?

Miners in the Habsburg army have a tradition dating back to 1716, when they were attached to the artillery corps by order of Eugene of Savoy.[19] But their first big moment came in 1762 during the legendary defence of Schweidnitz.[20] This was important for several reasons. It was one of those exceptional cases where a fully developed underground war took place, including the first combat use of compression mines (Globe de Compression). Coincidentally, there were two Frenchmen on the side of both the Prussian attackers and the Austrian defenders. The Prussian work was led by Major Le Fevre and the Austrians were led by General Gribauval. Both had experience with the work of another French engineer, Belidor, who was involved in practical experiments with underground mine explosions.[21] The underground war lasted several weeks and became the theoretical and practical basis for the mining activities of Austrian and Prussian armies at least until the end of the 18th century.

Following the success of the mining defense of Schweidnitz, which delayed the fall of the fortress by many weeks, this special type of army was first expanded to two and then four companies of 464 men in 1763 and 1770 respectively. They were newly led by Major Albrecht Heinrich Schröder under the name 'Mineur-Brigade'. They were sent to Petrovaradin, where Schröder led work on the local mine system, which he designed

16 Cf. J. HOFMAN, *Vlasti k obraně, matce ke cti*, pg. 141–155.

17 Ibid., pg. 151.

18 Many plans of the fortress' mines bear his signature, see Plans of the Terezín Fortress, I K – III/K.

19 Heinrich BLASEK – Franz RIEGER, *Beiträge zur Geschichte der k. u. k. Genie-Waffe I*, Wien 1898, pg. 185.

20 J. TIELKE, *Die drey Belagerungen und Loudonische Ersteigung der Festung Schweidnitz*, pg. 151 and onwards.

21 See his work: David Andreas SCHNELLER, *Herrn Belidors vermischte Werke*, Braunschweig 1769.

himself, and he even carried out test explosions there.[22] From 1770 at the latest, when Schröder was already a colonel, one of his deputies was Major Ludwig Mikowini von Brzesnobanya, and Matyáš Březina also served as a first lieutenant.[23] The 'Mineur-Corps' was attached to a separate engineering corps (Genie – und Fortifications Amt).[24] Major Josef Pavlíček (Pawliczek) took over the command, and Mikowini became his deputy, especially for technical matters.[25] It was Mikovini who later led the mining work in Terezín as a colonel. Management of the construction works itself was entrusted to captain Březina.[26]

We made this small digression to make clear the ideological connections and experiences of the authors of the Terezín underground. The underground war at Schweidnitz in 1762 was conducted in the spirit of Belidor's theoretical teachings and practical experiments. This was continued by Major Schröder, together with the miners who survived the defense of Schweidnitz, who directly referred to it in his test explosions, which he carried out repeatedly in Petrovaradin.[27] Mikowini and Březina also participated, along with the construction of the local mine system. The local tunnels still bear their signatures.[28] Although we cannot prove the direct participation of either of them in the defense of Schweidnitz, they were from the same generation and their professional knowledge must therefore have stemmed from the intellectual environment defined by Belidor and Schweidnitz. In Terezín, Mikowini is mentioned as the commander of the mining corps, and Březina's signture is found on many drawings of the underground tunnels. This is also evidenced by a note in captain Würth's proposal for the modernisation of the Terezín underground from

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22 On his work in Petrovaradin: Nenad ŠEGULJEV, *Miner Corps in Petrovaradin*, GRAĐA za proučavanje spomenika kulture Vojvodine Pokrajinskog zavoda za zaštitu spomenika kulture 2022, vol. XXXV, pg. 141–149.

23 H. BLASEK – F. RIEGER, *Beiträge zur Geschichte I,* pg. 187.

24 Ibid, pg. 189.

25 Ibid, pg. 198.

26 SAME, *Beiträge zur Geschichte II,* pg. 42.

27 *Beschreibung der Minen-Experiments, welches im Monat September des 1765igsten Jahrs zu Peterwardein vorgenommen worden* [online]. Available at: https://www.manuscriptorium.com/apis/resolver-api/cs/catalog/default/detail/manuscriptorium%7CAIPDIG-VHUP___IIR_C_3672___0463RI3-cs [cit. 2025-12-06].

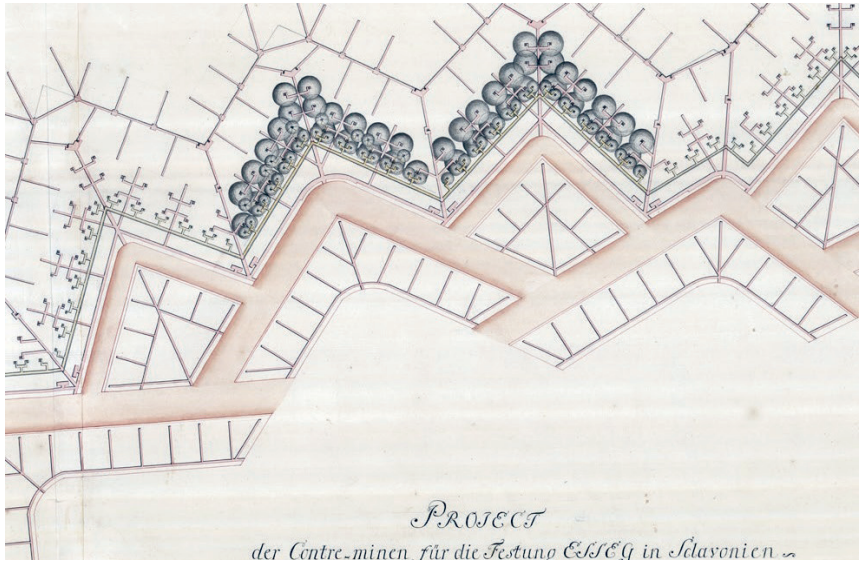
28 N. ŠEGULJEV, *Miner Corps in Petrovaradin*, pg. 147.

1828: '*In 1787, I was a miner for Major General von Březina, the captain of his company. Before the experiments in 1787, I was writing in his office for weeks, and I often heard that two test mines were first detonated so that the remaining charges for the experiment could be calculated according to Colonel Schröder's rule (…).*'[29]

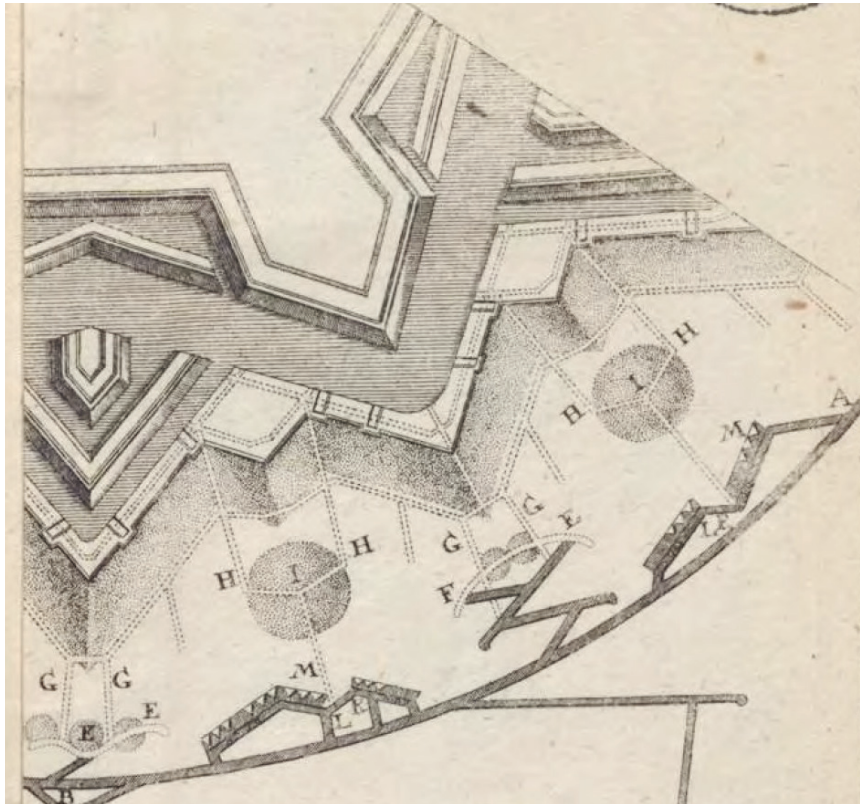
If we compare Belidor's mine system designs with the Terezín tunnels, we will find many similarities. The main one is the system itself, consisting of the main gallery and the envelope connected by communication galleries, with the addition of listening galleries, places-of-arms and retrenchments. The oldest form of the Terezín underground also contains two more levels of mine branches extending from the main gallery. Belidor also accounted for these, but they were only to be built during the siege itself.[30] The fact that they are already built in Terezín can probably be attributed to the Austrians' efforts to ensure that their mine system was as ready as possible for defence, and that only a minimum amount of construction was needed during the expected battles themselves. They were also built from the beginning in Josefov and Petrovaradin. Whether the local mine system was designed by Mikowini or Březina (or someone else), he certainly followed the ideas of Belidor applied by Schröder in the Austrian environment.

[29] *Gehorsamste Bemerkung über die eingesender werdenden Plans und Schriften*, Governor Franz Würth in Terezín 21 following 1828, Plans Collection Terezín, III K 29.

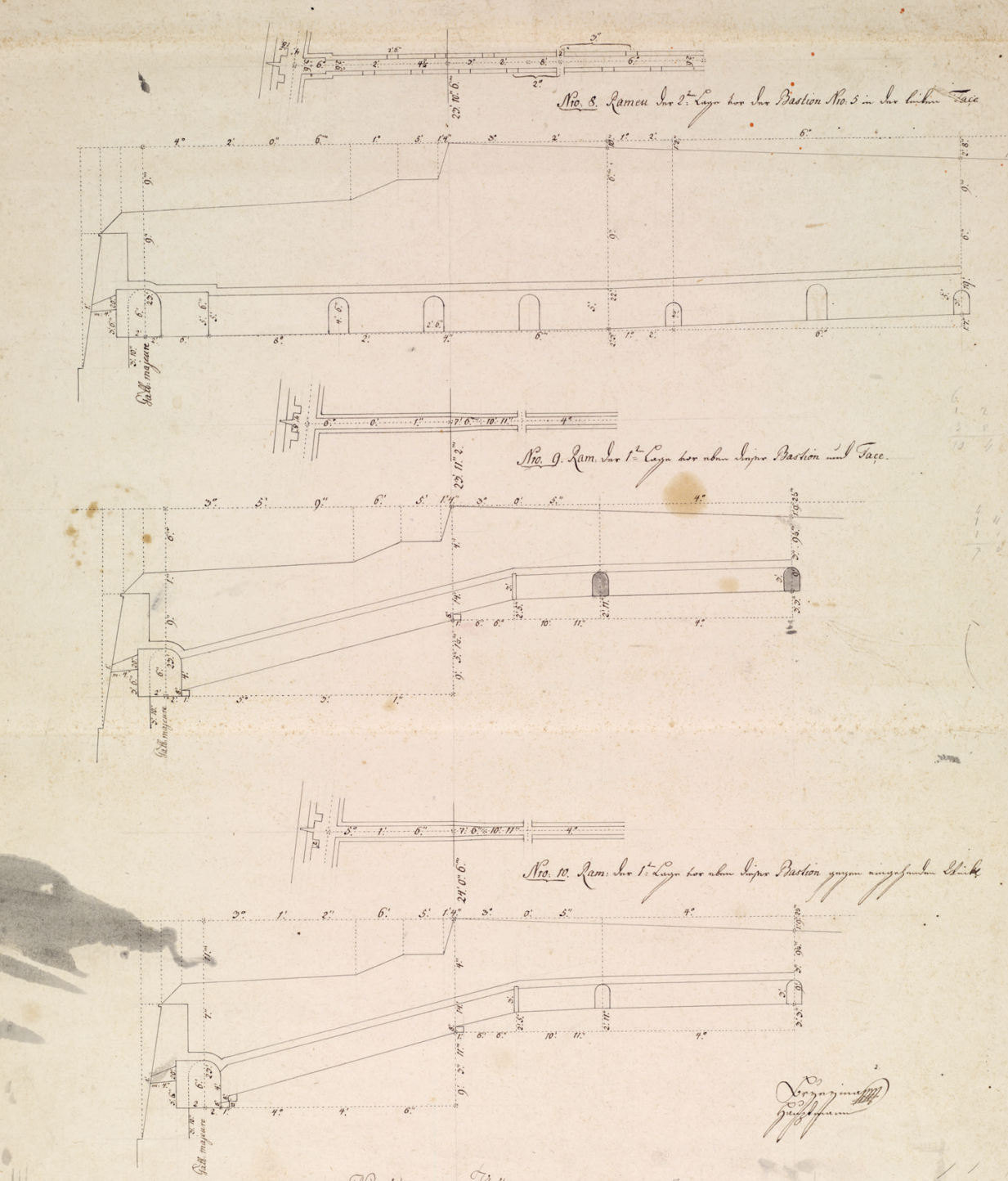
[30] D. SCHNELLER, *Herrn Belidors vermischte Werke*, pg. 156.



Detail from the plan of Schröder's counter-mine system design for the Osijek/Esseg fortress (Kriegsarchiv Wien).



Siege operations against a fortress utilizing approaches and batteries, illustrating the disposition of the defenders' mine galleries according to Belidor (D. A. SCHNELLER, Herrn Belidors vermischte Werke).



Design of individual mine branches in Terezín (VHA, undated – 1780s).

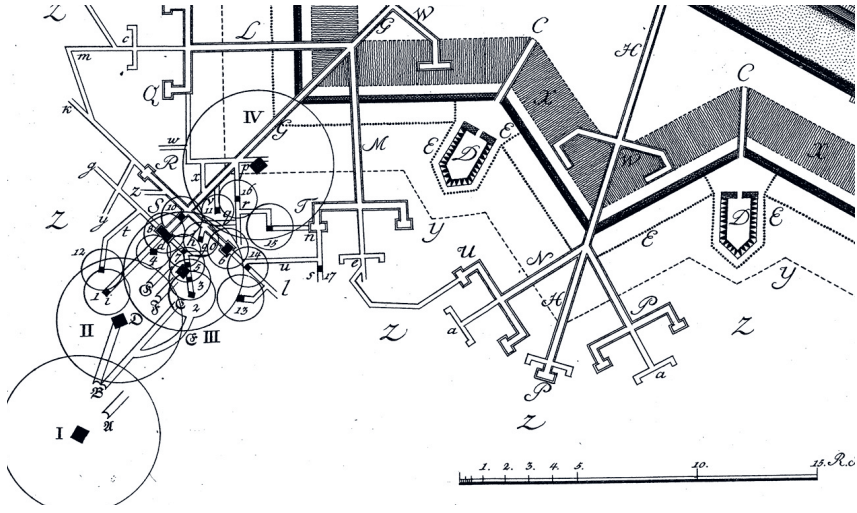
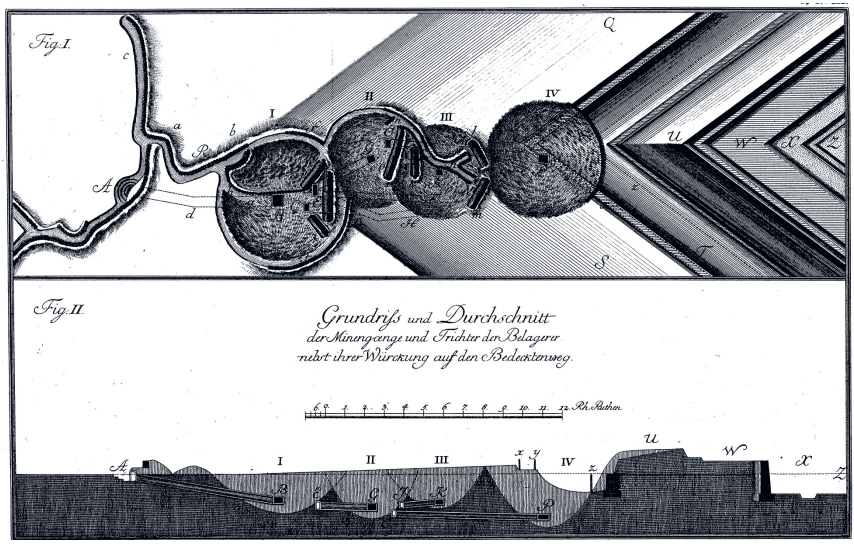


Plate illustrating subterranean warfare during the Siege of Schweidnitz in 1762 – plan view (J. TIELKE, Die drey Belagerungen und Loudonische Ersteigung der Festung Schweidnitz).



Prussian advance using globe of compression explosions during the Siege of Schweidnitz in 1762 (J. TIELKE, Die drey Belagerungen und Loudonische Ersteigung der Festung Schweidnitz).

Projects and construction methods

A remarkable and eloquent layering of plans that reveal the conceptual thinking described above has been preserved for Terezín. Unfortunately, there are no surviving records that could determine exactly when construction of the counter-mine system began. So let's take a look at the project work first. We won't go into detail about individual regulations or textbook rules written by Belidor, Bouchard and other authors; instead, we will focus on the fortress's counter-mine system itself.

Let's start with the morphology of the terrain before construction of the fortress began. The preserved technical drawing of the sectional views of the walls in the lines of the main structures documents both their location in the terrain, and, most importantly, the location of the main galleries[31]. It is evident from these drawings that the galleries were placed so deep below the terrain that the original surface covered the crown of the tunnel.

When we look at other report plans, we find a number of documents showing the original height ratios and the extent of the necessary excavation work. Working sketches also document the conceptual design of the main artillery gallery in the counterscarp[32]. The capital of ravelin No. 18 is a specific example showing that the original terrain here lay at a vertical level 36 feet from the projective plane. According to the drawings, the floor of the main gallery in this spot is at a vertical level of 48 feet, and the top of the tunnel at 41 feet, meaning the bricked cover of the tunnel is at 40 feet. The main gallery is therefore approximately 1.3 m below the original vertical level.

If we proceed further, we find that the envelope floor was placed about 0.4 m higher than the floor of the main gallery, and the listening corridor was even 0.46 m higher. Most of the counter-mine system was deliberately installed in the original terrain, which helped save time and money due to several factors. The primary fortification principle is the construction of fortifications in vegetated terrain, which balances the ratio of excavated and piled soil.[33]

One of the main benefits was the ease of construction from the surface or from shallow excavations. Another advantage was the elimination of problems with subsidence and uneven cohesion of the excavated soil over the years. This also significantly reduced the volume of earthworks and

[31] Plans of the Terezín fortress, plan I C/y9 profiles of fortifications and terrain.

[32] Ibid., plan I K/a02 Original plan according to which mine galleries are to be established.

[33] In current terminology from French, '*déblai – reblai*'.

the costs of their preparation. Finally, natural terrain has a higher density and lower water permeability than fills, and it also makes potential mining by besiegers harder. Construction from the surface is therefore not only cost-saving, it is also faster than tunneling.[34]

Plan sketches, or technical drawings with handwritten notes, mostly in pencil, are another interesting group. This includes both the above conceptual plan of the main gallery[35], as well as designs for the layout of entrances from the main moat[36] and other similar documents.

The next step to determine the exact location of each structure is to outline the plan in the field. Documentation of this stage of construction has been preserved to a considerable extent. We have layout drawings available that determine the position of the main survey pegs on objects structures and their relationship to individual points in the counter-mine system. Each corridor is determined by its axis leading from the relevant junction points — a junction is an intersection of corridors, entrances to depots or the base of main structures — and further by the distances between individual junctions and the relevant angles formed by these axes. Military engineers precisely staked out a counter-mine system on the original terrain plain.[37]

Detailed technical drawings[38] were used for earthworks with precisely defined parameters, such as the location, width and depth of individual tunnels and depots, as well as their alignment. This level of refinement enabled efficient work progress and significant cost minimisation — both for the excavation work itself and for the subsequent filling, preparation, and transportation of the soil.

For the purpose of construction savings, effective management of construction processes, and to maintain a certain degree of defense capability of the fortress during its construction, it can be clearly determined in Terezín that the undeveloped, but necessary space for the implementation of the counter-mine system was the area of the attack line between bastions No. 3 to No. 5. As mentioned above, most of this section had the floor of the corridors located approximately 1–1.3 m below the vegetated terrain, with the foundation structures extending to the appropriate depth

34 Cf. J. HOFMAN, *Vlasti k obraně, matce ke cti*, pg. 213.

35 Terezín fortress plans, plan I K/a02 Original plan according to which mine galleries are to be established.

36 Ibid., plan III 1/097.

37 Ibid.

38 Ibid.

below, depending on the type of element. The foundations were most often formed by foundation belts, with a significant gradient at the entrance to the tunnels towards the main gallery, up to the vertical line of the assumed position of the main gallery. At tunnel intersections, the foundations were formed by pillars connected by a vault system. There are naturally also certain construction nuances — the two upper levels of the arms can be supported by a 2.2 m-high wall in one case, and by a pillar with vaults of the same height in another. This isn't a rule or principle, but rather a reflection of the terrain morphology and a decision of the builder or designer, while maintaining the element's required function and durability.

At the time, the construction of the corridors advanced from the envelope towards the newly dug main moat, namely the counterscarp with the main gallery. The view of the construction site must have been very interesting — it would have been possible to see the lines of corridors either excavated into terraces or led in covered pits, but also the wooden scaffolding surrounding the future foundations of the corridors of the upper floors, or the ongoing brickwork with simultaneous backfilling. These stages are still clearly observable today, both during reconstructions of underground passages and on report plans, especially from 1784 and 1785.[39] The same situation is also documented in the plan of the unfinshed fort from 1783.[40]

By the end of 1783, the entire envelope between bastions No. 3–5 had been completed, including places-of-arms, retrenchments, and listening galleries. The adjacent communication galleries were also completed. Mine branches were already developed in the structures of place-of-arms No. 31, ravelin No. 18, counterguard No. 22 and place-of-arms No. 32 at this time.[41]

But disaster struck in early 1784. At the end of February of that year, a major flood devastated Bohemia. On 28th February, the water in the Elbe began to rise rapidly, pushing against the construction site through the Ohře riverbed. The following day, the pressure of the water, supported by ice floes driven by strong winds, broke the dams protecting the construction site and the flood penetrated the unfinished fortifications, and subsequently also the completed mines. The consequences were particularly devastating here. The first damage survey in early March, before the

[39] Cf. Terezín fortress plans, plan I K/a04 and I K/a10.

[40] Luboš HRUŠKA, SHP Obnova severní části vnějšího podzemního systému, Ústí nad Labem 2016, pg. 66-67.

[41] Cf. Ibid., plan III K/09 and plan III K/30.

water had receded, paints a picture of devastation: '*The mines suffered the most, namely those in front of the polygons of bastions III and VI, much more than those in front of IV and V. This is due to the fact that the terrain in front of III and IV is sandy and required more backfilling. The survey seems to show that the envelopes, galleries, listening galleries, communication galleries, places-of-arms, and retrenchments, most of which have collapsed, are currently inaccessible. From bastion III to bastion IV, there are 257 standard fathoms* (approx. 488 m — author's note) *that need repair. It is necessary to demolish 186 standard fathoms* (approx. 353 m — author's note) *of the badly damaged galleries and restore 136 standard fathoms* (approx. 258 m – author's note) *of the completely collapsed galleries. From bastion IV to bastion V, which did not require as much backfilling due to the firmer subsoil, it is necessary to repair 115 conventional fathoms* (approx. 218 m — author's note) *of heavily damaged shafts and 18 fathoms* (approx. 34 m — author's note) *of collapsed tunnels. Most of the internal retaining walls* (e.g. *Wiederlagsmauer* — author's note) *were torn from above, the vaults resting on them collapsed and the paving stones fell to the bottom. Level 1 galleries, both before IV and V, and before IV and III, suffered no damage, only some communication galleries leading from the lower floor upwards*.'[42]

The damage was not just caused by the flood water itself, but also by the subsequent subsidence of the soil in the construction site area. This damaged almost all built tunnels. Only a small amount remained untouched; most needed to either be completely repaired or rebuilt. The entire envelope in front of counterguard No. 21 collapsed, including the listening galleries, places-of-arms, and retrenchments. A very similar situation occurred in the tunnels in front of place-of-arms No. 31, and the other passages weren't much better off. Therefore, the vast majority of the work up unto that point was for nothing.

Military engineers documented the flood situation and the problems described above on a site plan[43], which records the height of the flooding of the tunnels in a cross-section along with a comparison of the flood level against the normal state of the Ohře River.[44] This shows us that the normal river level was 9 feet (2.925 m — authors' note) below the floor of the main gallery, whereas during the flood it reached up to 7 feet (1.977 m — authors' note) above its floor. The subsequent drop was only 1 foot (0.325 m — authors' note). The water therefore flooded the tunnels all the way up to the ceiling.

42 GD Terezín, box 5, reports of the flood from 1784.

43 Terezín fortress plans, plan III K/09 and III K/30.

44 Ibid., plan III K/31.

After the flood damage was removed, the next phase of construction could begin, namely the construction of the counterscarp, including the main gallery. We can follow this process well using the example of a section of ravelin No. 18. We know from preserved plans and reports that the counterscarps in front of the left front side and capital were built up to the height of the loopholes, and even higher in front of the right front side. In Terezín, however, there is no uniform, continuous vertical alignment; construction took place in batches, in individual sections, corresponding to the extent of the scaffolding that was currently in place. These sections can be identified in the report plans, which refer to accounting books and other records of work with their notes — usually in red pen.[45][46]

The hierarchy of colour marks allows for a detailed reconstruction of the construction process of the counterscarp and the main gallery, including the construction joints and the foundation itself. The plans[47] show that the oldest masonry is the masonry of the counterscarp and the outer wall of the main gallery up to the base of the vault. This was followed by the covering of the corridor with a vault, and only then was the crown masonry of the counterscarp built. We can assume that work on the counterscarps continued until 1786 or 1787, when they gradually moved to the area of the covered way itself above the main gallery.[48]

The covered way once again shows the precision of the engineers of the time. They carefully measured the crown of the glacis, namely the line of the crown of the breastwall of the covered way, always in direct connection with the counter-mine system. This line defined the space of individual mine branches. The branches located below the crown line were equipped with grooves and fitted with an eight-inch step. This design reduces and narrows the mine branches relative to the branch spaces. The axis of the upper galleries is situated directly below the line of its crown to ensure the defensible nature of the covered way.

For the year 1787, we also have documented sections of corridors in front of the floodplains, i.e. between place-of-arms No. 25 and ravelin No. 16, and further between ravelin No. 19 and place-of-arms No. 36. These are very simply designed sections: the corridors here are formed by the main gallery in the counterscarp, the communication gallery under the place-of-arms, and the built-in entrances to the arms of the mine branches. Upper

45 Ibid., Profil von Place d´armes Nr. XXXII

46 GPA Theresienstadt, Nr. 38 Lit.K Plan Ravelin Nr. XVIII

47 Ibid.; Terezín fortress plans, plan I E/b18.

48 Ibid., covered way plans I E/b20 and I F/a19.

galleries are established in front of each ravelin, which only lead to the axes of the lower arms of the mine branches on both sides.

This is documented until 1787. Then there are drawings that depict the connection of the unfinished upper galleries in front of ravelins No. 15, 16, 19 and 20, simultaneously with the laying of counter-mine arms in these galleries and the extension of their routes. This work was carried out by boring from the already finished surface of the glacis using dug wells. These wells are most likely still preserved under the current vegetation, covered over during later land development.[49]

It can therefore be summarised that these sections were implemented primarily with regard to the phasing of the construction of the entire fortress.[50] It was primarily a practical, construction/organizational solution.

Several passages on the offensive line were also mined, especially in the section in front of counterguard No. 21.[51] The time frame for the construction of the local mine system of the Main Fortress was the period from 1782 to 1788. Construction of the Small Fortress took place much later.[52] For the sake of completeness, we should add that according to the preserved plans, the Small Fortress system was mostly built from the surface, but we cannot rule out that some parts were excavated by mining, just like the Main Fortress.

The underground system was precisely mapped and documented at the time of the fortress's 'final approval', and it is thanks to this set of plans that we can now observe the original intention of military engineers and the resulting form of this ingenious and technically remarkable complex.

The Terezín fortress archive contains a unique set of planning documentation, according to which it would still be possible to rebuild a counter-mine system on an open plain today, and not only on the offensive front. Due to a lack of manpower, we used 3D modelling, which — even based on more than 240-year-old plans — allowed us to create a very accurate representation of the section of the future open-air museum, the creation of which is declared by the government programme.[53] The 3D model will be used to make a physical model to scale.

49 Terezín fortress plans, plan III 1/097.

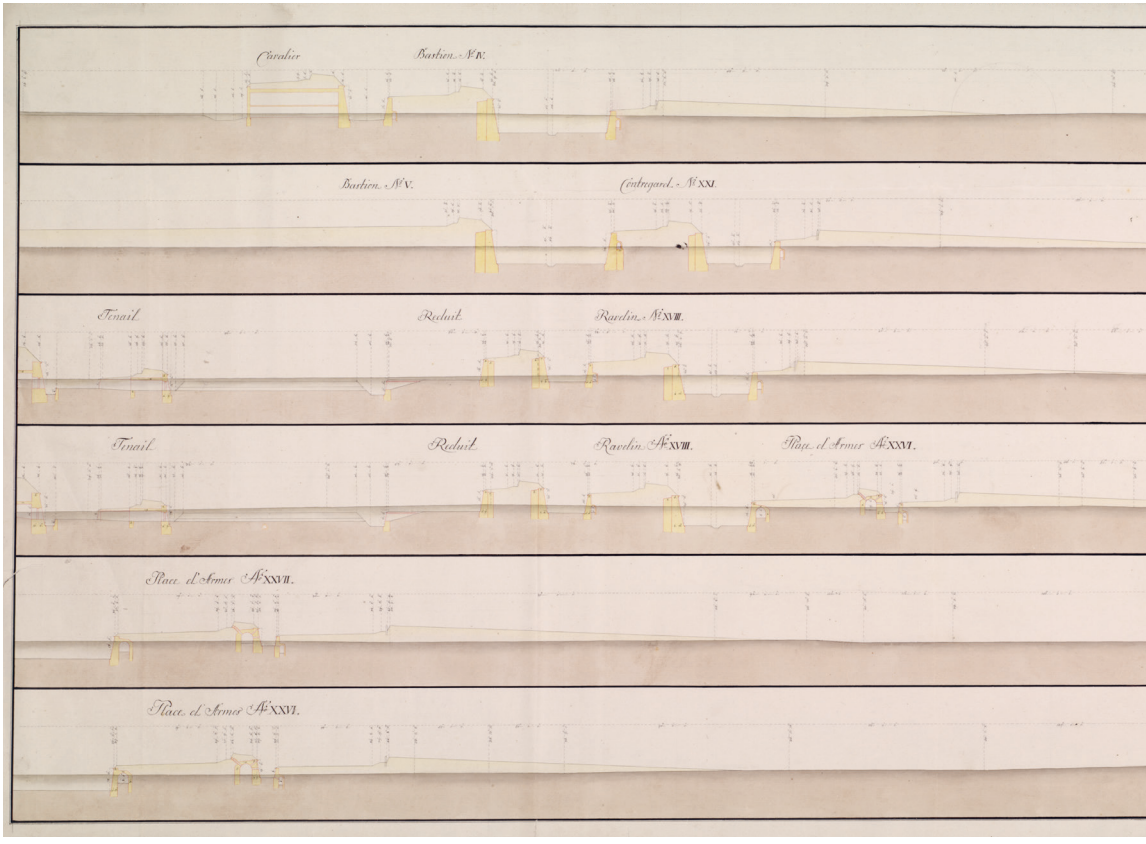
50 Cf. Terezín fortress plans, plan I D/a01 plan of the Terezín fortress for the year 1783.

51 Ibid., plan I K/a06.

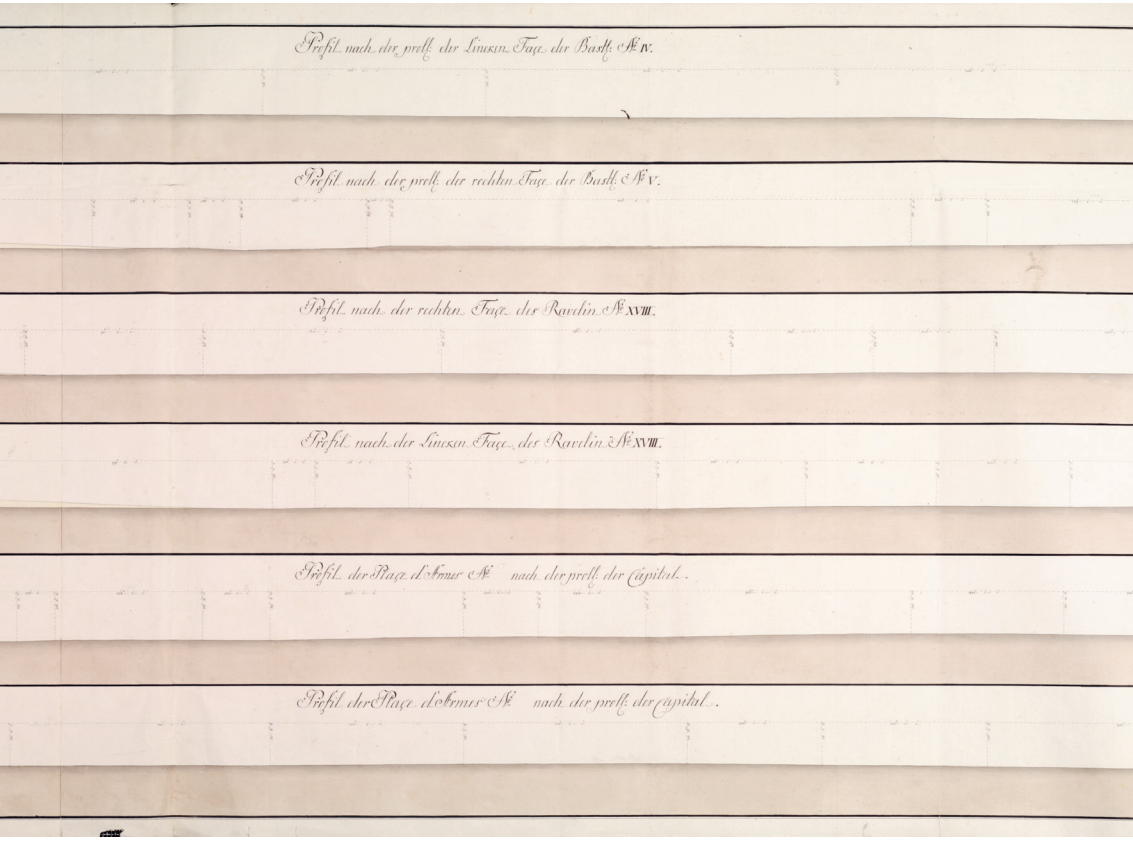
52 Ibid., plan I K/b05.

53 National subsidy of the Ministry for Regional Development of the Czech Republic, programme No. 117 27 – System programme for the restoration and development of the fortress towns of Terezín and Josefov.

Landscape plan of the area prior to the construction of the fortress (VHA, undated – likely c. 1780).



Plan of sectional elevations along the capitals of the main structures of the Main Fortress western front, depicting the original ground level (VHA, undated – likely c. 1780).


Profil nach der prell. der Linckn Face der Baſtl. № IV.

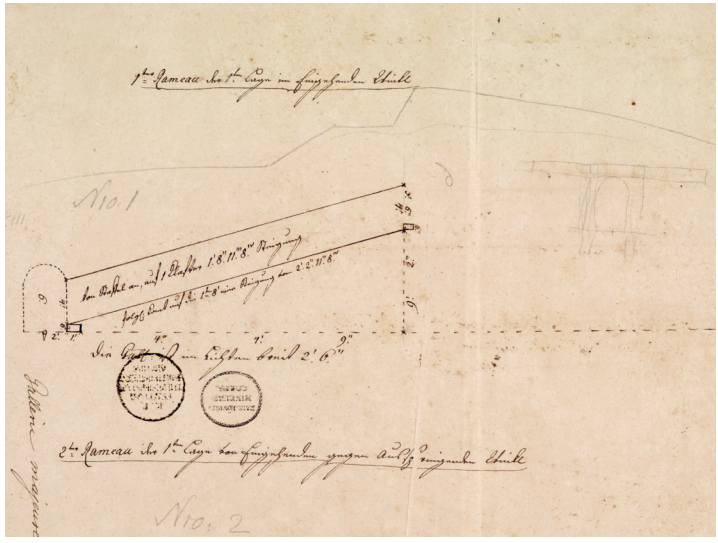
Profil nach der prell. der rechtn Face der Baſtl. № V.

Profil nach der rechtn Face des Ravelin № XVIII.

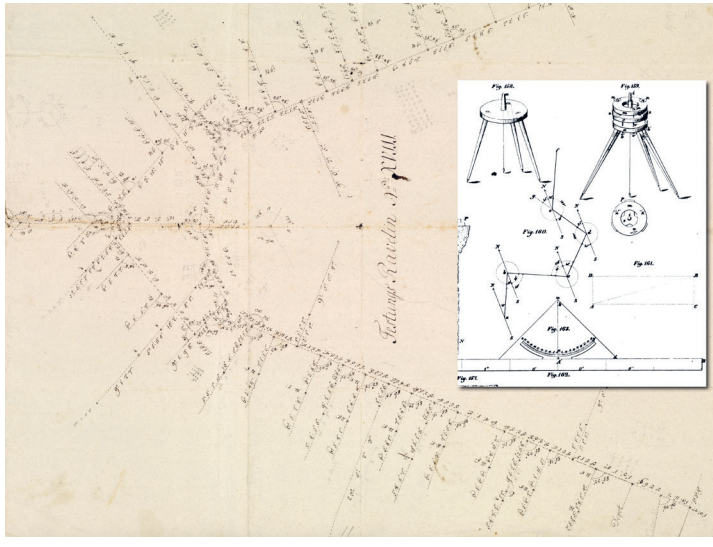
Profil nach der Linckn Face des Ravelin № XVIII.

Profil der Plaçe d'Armes № nach der prell. der Capital.

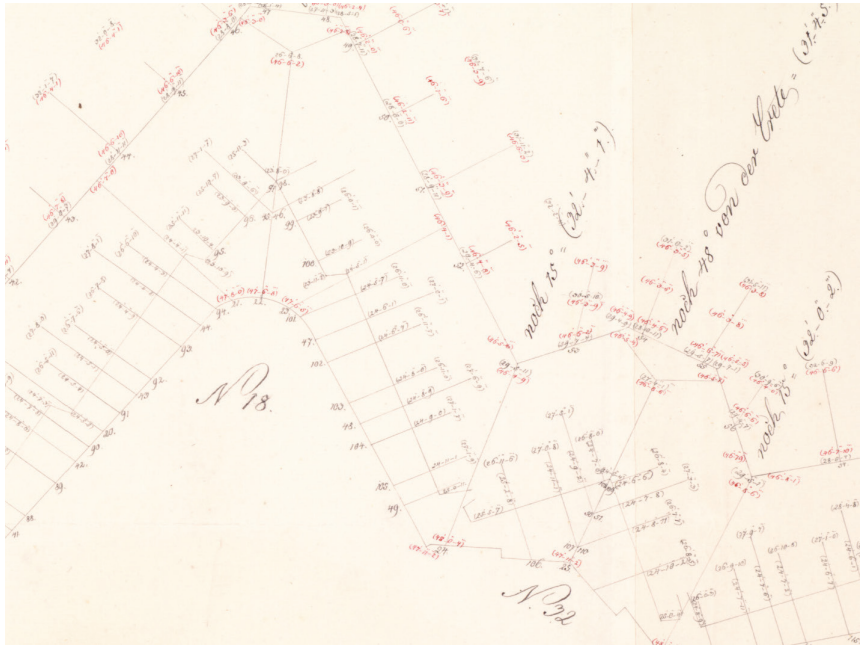
Profil der Plaçe d'Armes № nach der prell. der Capital.



Layout plan for the establishment of **level 1 mine branches** No. 1, featuring a sketch of the rampart line and the construction principle (VHA, undated – 1780s).



Setting-out ground plan of the galleries in front of ravelin No. 18, including a mining theodolite (VHA, undated – 1780s).



Setting-out plan of the galleries in front of ravelin No. 18, including the vertical alignment of individual galleries (VHA, 1822).

Left: Individual layers of backfill above the vault of the main gallery in front of bastion No. 4 during the 2016 repairs. Right: The visible distinction between the original ground level and the subsequent backfill of a **level 1 mine branches** in front of ravelin No. 18. (Jiří Hofman).

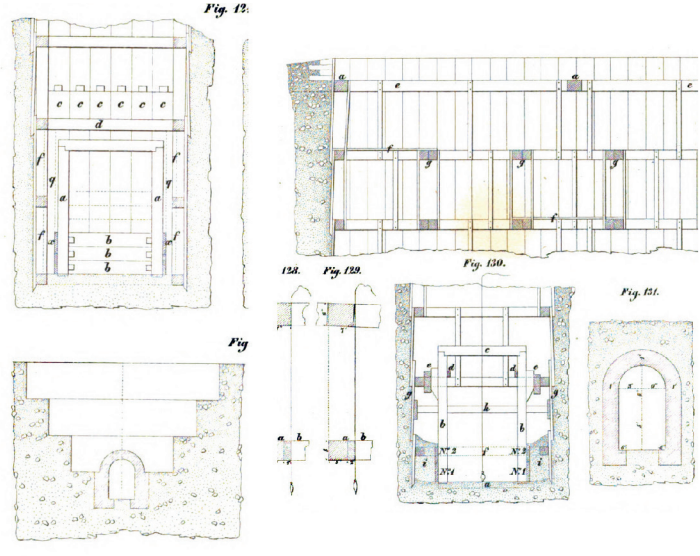
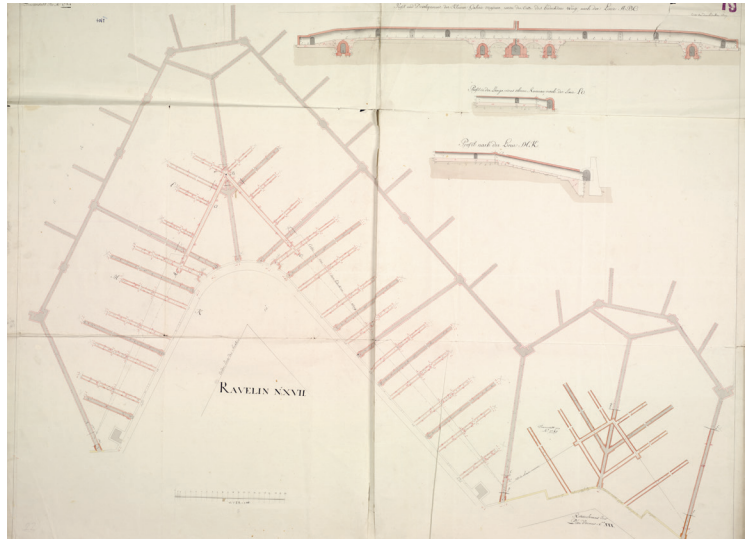
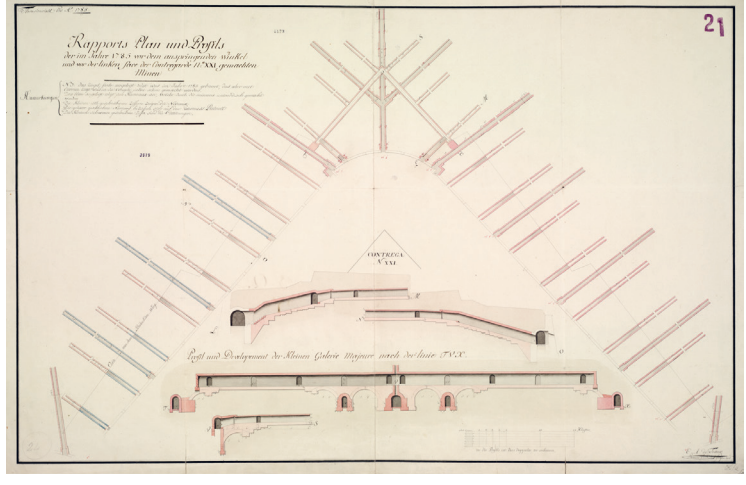


Illustration of the gallery construction principle using construction pits, the most common method employed in Terezín. (Author archive).



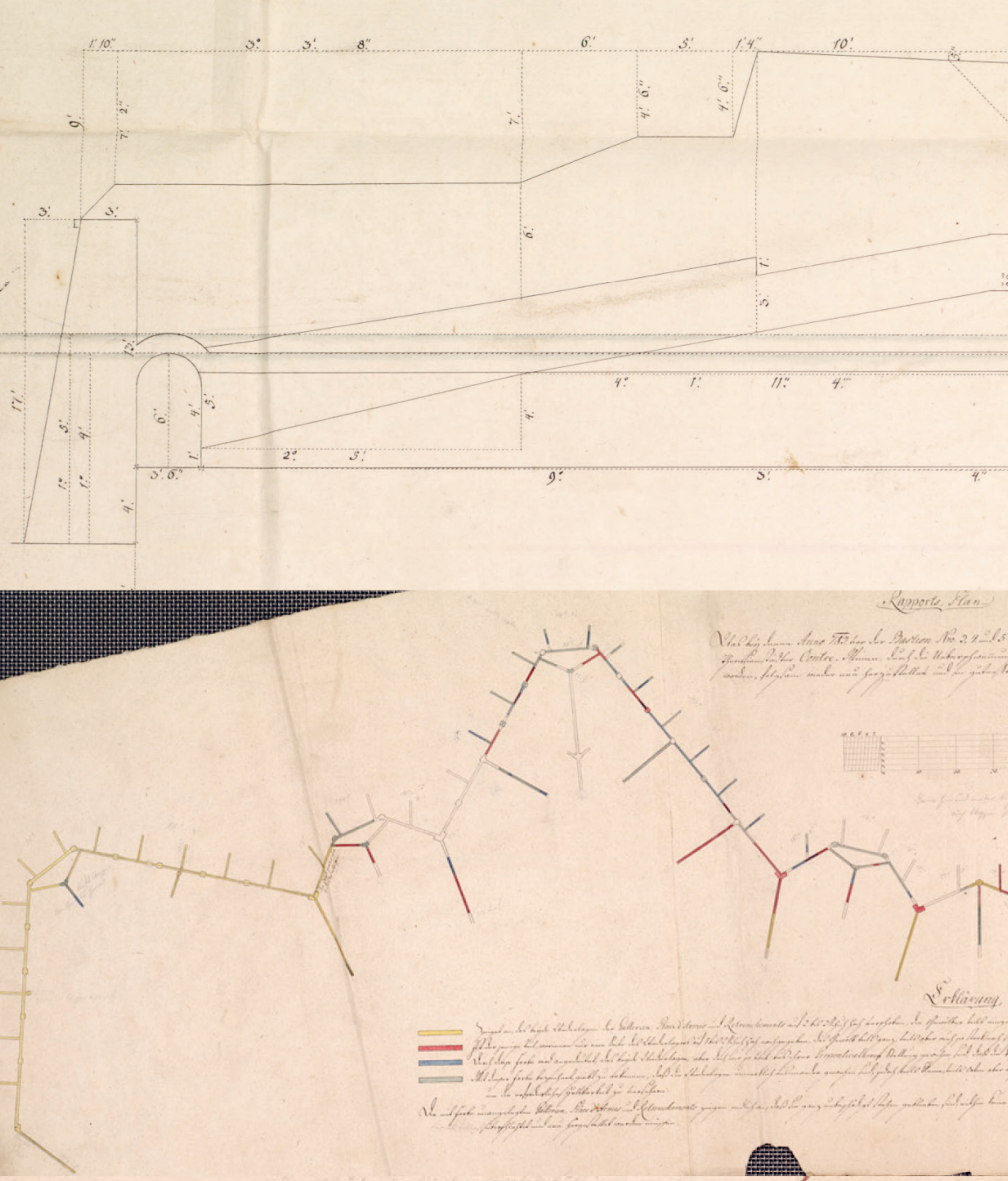
Rapport plan of the gallery construction in front of ravelin No. 17 as of 1784, documenting the progress of works – grey: structures completed before 1784; red and yellow: structures built in 1784; outlined: planned structures. (VHA).



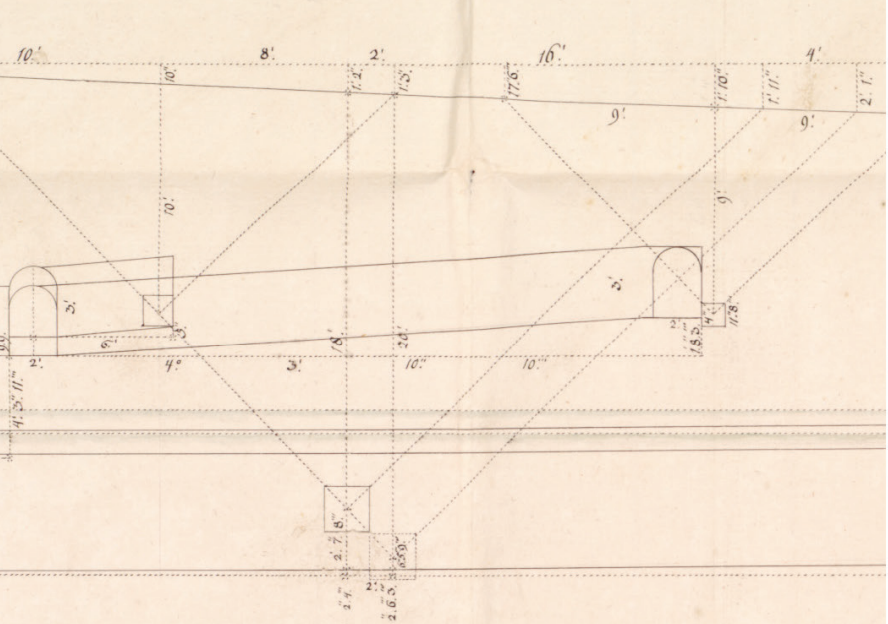
Rapport plan of the gallery construction in front of counterguard No. 21 in 1785, documenting the progress of works – blue: galleries excavated using mining methods (VHA).

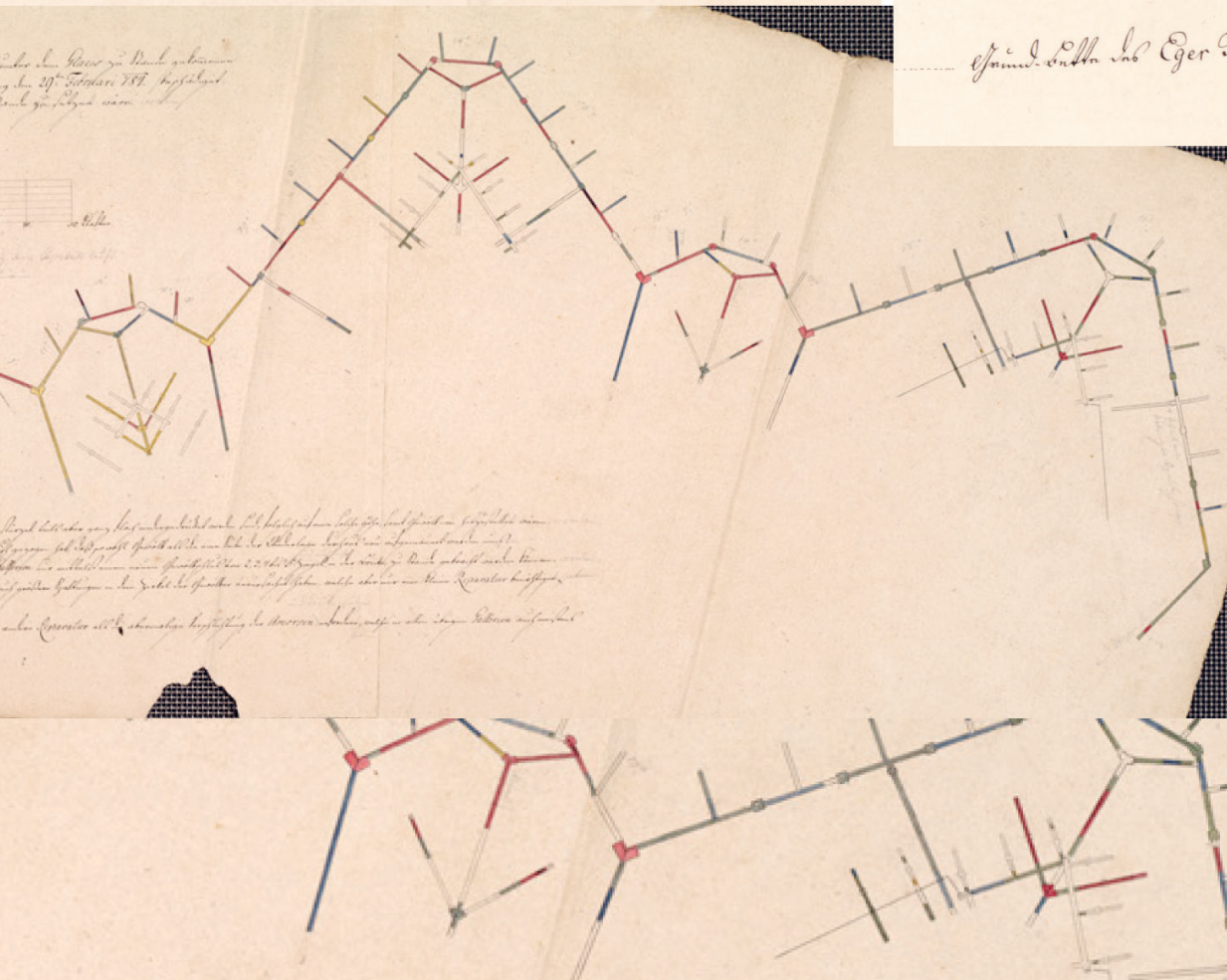
Documentation of the construction progress of the galleries between bastions No. 3 and 5 as of 1783 – red denotes already completed galleries. (VHA).

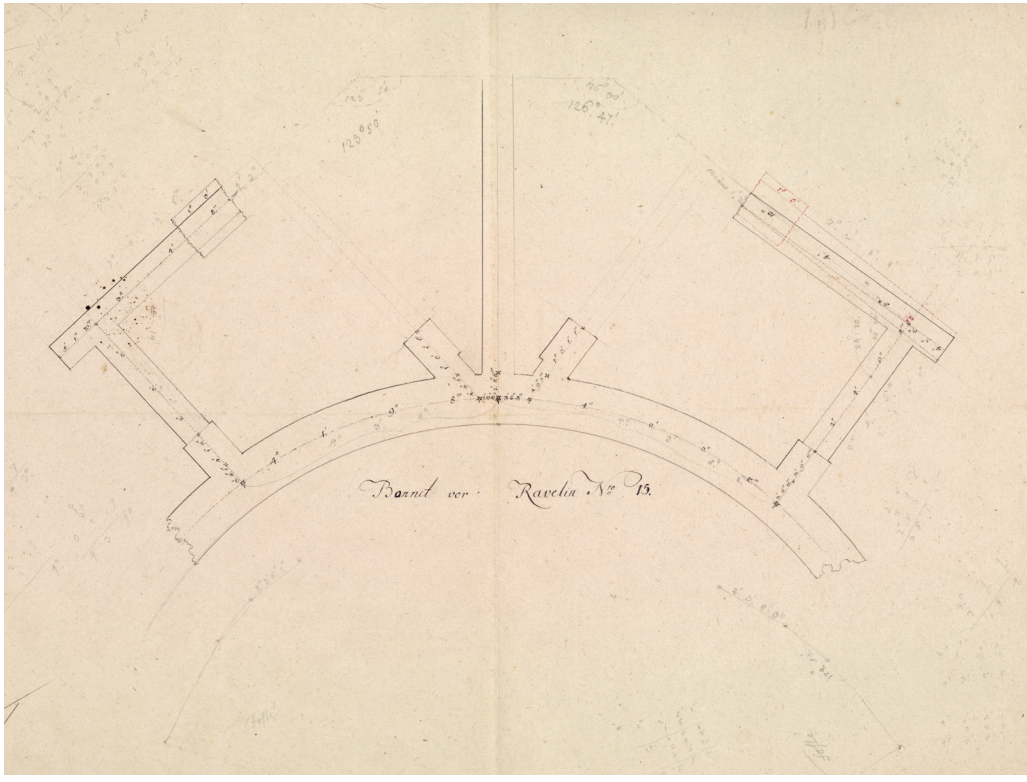

N.XXVII
N.XXVI
N.XXVIII
N.XXII
N.XXVIII
N.XIX.
N.XXVII



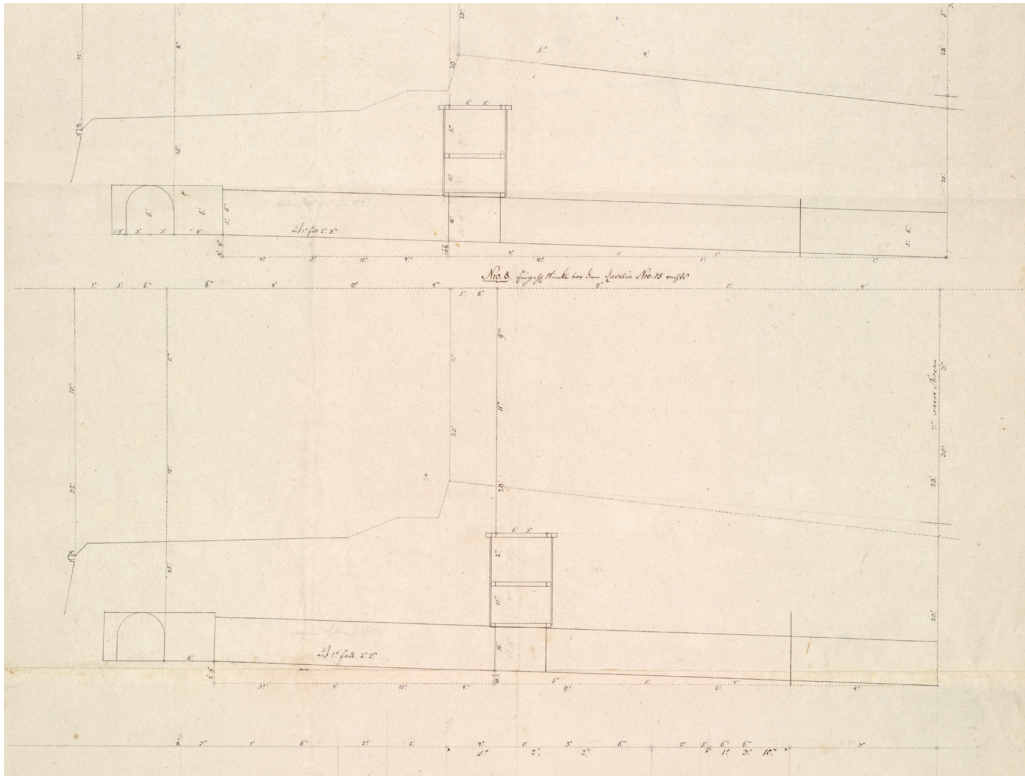
Documentation of the state of the subterranean galleries following the 1784 floods. The cross-section clearly indicates the normal water level and the flood water level. Various types of damage are color-coded, ranging from complete destruction requiring reconstruction of the masonry to localized repairs. (VHA).


10'
8'
2'
16'
4'
9'
9'
höchster Stauwr Horizont
höchste Inondations Höh





Drawing of the subterranean layout in front of ravelin No. 15, which was only initiated from the surface, with completion planned via mining (VHA, undated – 1780s).



Sectional elevation of the mine galleries in front of ravelin No. 15, including mining shafts for the completion of gallery construction via mining (VHA, undated – 1780s).

Function

In addition to the walls and water, the mine system was a key part of the defence of the Terezín fortress. As we have seen, its intended use was defined by contemporary military manuals and, in particular, practical experience from the underground war in Schweidnitz in 1762.

The corridors under the glacis were intended to prevent the attacker from advancing towards the covered way, capturing it, and subsequently breaching the fortifications. Not wanting to attack across the open plain into the deadly infantry and artillery crossfire of the defenders, the customs of 18th-century warfare dictated advancing through approach trenches (saps and parallels). Once the besieger reached the foot of the glacis, his positions were above the defenders' mines, who were able to destroy them with underground explosions. A properly detonated mine could instantly destroy key points in enemy trenches, thwarting many days of work and killing dozens of soldiers.[54]

If the besieger fought his way through the glacis, the next phase of the attack on the fortress began — the so-called 'crowning of the covered way'. Here, the attacker used trenches, sandbags, and earthen ramparts to try to gain a foothold on top of the covered way. In this elevated position, the besieger dominated the otherwise open space of this first fortified line and was able to easily drive the defenders away. The mines also came into play at this point, allowing such enemy nests to be easily destroyed by underground explosions.

But the most significant moment came as soon as the attacker began to construct an artillery battery. If, after crowning the covered way, the enemy managed to drive all the defenders away from here, he built a fortified artillery battery here, which opened close-range fire into the opposite wall with the aim of breaking through it. Putting this together was challenging and lengthy, and as it was done while the bullets of the defenders rained down on them, it also cost the lives of many soldiers. And just before the devastating fire of this battery began, the defenders were to detonate a prepared underground mine underneath it, which literally turned their many days of effort into a pile of rubble.

The structure of the mine system also corresponds to this simplified division of functions. The main and communication galleries, as well as the envelope, formed the basic connecting network for the transport of people, material and gunpowder. The listening galleries served as a basis for new tunnels dug from demolished niches, at the ends of which mines were placed to eliminate the attacker on the surface of the glacis. Simply

[54] P. WOHLMUTH, *Krev, čest a hrůza*, pg. 227 and onwards.

put, this is the first line of defence. The second line consisted of mine branches extending on two levels from the main gallery. These densely intertwine the space of the forefield of the covered way, which the attacker must crown and where he will subsequently set up his artillery batteries.

Furthermore, the system is extremely variable due to its simplicity and the huge number of walled-in niches, allowing for the digging of ever new tunnels in any section of the underground, in any direction.

As is evident, the targets of mine explosions were primarily immobile objects — trenches, batteries, cannons, etc. The reason for this is the time-consuming process of preparing a mine for detonation. The naturally humid underground environment did not allow for the preparation of a mine too long before it was detonated, as the gunpowder would simply get wet.

There was a small niche in the mine chamber, into which boxes or barrels with a pre-calculated amount of gunpowder were placed. This quantity corresponded to tables derived from the strength of the powder, the depth of the mine, and the type of terrain in which the charge was located. When filled with gunpowder, a mine chamber turned into a mine furnace, in the terminology of the time. A corridor or tunnel led from it, usually winding two or more times. The Terezín mine branches, which were already prepared for storing mines, were equipped with stops (slots) along the walls. This was essential for sealing the mine so that its explosion would take the shortest path to the surface, and not into the underground system. Beams were pushed into the slots, and the corridors were lined with sandbags and other beams wedged in the corners of the corridor. The length of this plug was to be twice the distance between the mine and the surface (the *'Wiederstandslinie'*).

A sausage ('*saucisse*' or '*Wurst*') was used for firing. This was a thin canvas tube filled with regular gunpowder that acted as a fuse — not unlike today's wine sausage. It was placed in a wooden channel with a square profile running from the mine through the entire seal to the launch point. The wooden channel protected the sausage from damage while sealing the mine, as well as from ambient moisture for a certain period of time. This had a certain drawback, as the channel disrupted the mine's seal, which caused the mine to 'blow' inward when fired.

Gunpowder burns extremely quickly without a delay, and the 'blow-off' of the mine made lighting a sausage on fire a highly dangerous situation. It was therefore not advisable to ignite it directly. This is where a simple device came into play, consisting of a wooden box with gunpowder and the end of the sausage placed in the bottom. In the top part, a plug with paper or other flammable material was inserted into the grooves, to

which a long string was attached. The miner lit the paper on the plug before firing. He unwound the string to a safe distance and used it to pull the plug out of the box. Then the burning paper fell to the bottom, where it ignited the gunpowder.

Fortresses equipped with these mines forced any enemy wanting to approach it with his trenches and batteries to first destroy its underground. This is how tunnel warfare began.

The attacker's goal was to get as close as possible to the defenders' corridors and then detonate a globe of compression ('*Druckmine*', '*Globes de Compression*' or '*Minés surchargées*'). These were huge. At Schweidnitz in 1762 they contained up to 2,500 kg[55], and at Valenciennes (1793) three mine furnaces were detonated with a total of 8,400 kg.[56] Their explosion had two primary consequences: its extreme force and vibration collapsed and buried the defenders' tunnels; it also created a crater so large and deep that it could have been used by the attacker to advance on the surface, and the amount of soil ejected was able to fill in smaller trenches and thus open up the fortifications against future attacks.[57] The actual and psychological effect of such an explosion was considerable.

There is a preserved record of the detonation of a globe of compression by the Austrians near Valenciennes in 1793 by eyewitness M. de Traux: '*The digging began behind the third parallel, 22-25 fathoms from the covered way* (less than 50 metres — author's note). *When the gallery was 37 fathoms* (over 70 meters — author's note)*, it was decided to detonate the globe of compression, because the miners could not continue further due to a lack of air. I saw for myself as they held their breath with the greatest difficulty. The almost complete lack of air was the reason why it was detonated. The fact that there was no enemy gallery within range of the mine is not the fault of the Austrian miners, as the direction was well measured. Part of the covered way was covered with rocks from the explosion. The horror of the defenders looking at the three terrible volcanoes aroused their fears that more might follow.*'[58] '*These explosions*', he continues elsewhere, '*were truly terrible and frightened the defenders so much that they offered little resistance and fled to the fortress. They abandoned all external elements including the large counterguard. Most units scattered. Many of them were torn to shreds and some*

[55] J. TIELKE, *Die drey Belagerungen und Loudonische Ersteigung der Festung Schweidnitz*, pg. 335.

[56] M. de TRAUX: *Die beständige Befestigungskunst, pg. 469.*

[57] J. TIELKE, *Die drey Belagerungen und Loudonische Ersteigung der Festung Schweidnitz*, plan VIII.

[58] M. de TRAUX : *Die beständige Befestigungskunst, pg. 470.*

were captured in the main moat near the underground tunnel in the curtain wall Monser. The attacking soldiers also found several miners in the mine corridors, all of which were loaded, and from which they tore the fuses.'[59]

The defenders defended themselves by digging their tunnels against the enemy, which first came out of the niches of the listening galleries. They used these to try to meet the approaching attacker's miners and place their own mine in their path ('*Dampfmine*' or '*Camouflet*').[60] *'These are mines that are placed near an enemy gallery to collapse it without making a crater or a mound on the surface, often suffocating enemy miners in the process.'* [61] The suffocation was caused by sulfur gases produced by the burning of gunpowder.

The great unknown in this underground duel of miners was the opponent's location itself. The defenders could see the enemy entering the underground from the walls, but they did not know the direction or depth. The only way to navigate was by listening, hence the listening galleries, because they were primarily used to listen to the progress of enemy miners. In the terrain in Terezín, the progress should have been heard at a distance of about 10 metres in normal soil conditions[62]. This is why the listening galleries are approximately 10 to 12 fathoms apart (19.5-23.4 metres — authors' note). The attacker did the same, working in his tunnels for a while and then listening to see if he could hear the sounds of the defenders. They had an advantage here, as their tunnels were already completed. They didn't need to put so much work into them. They just waited in silence until they heard the attacker's frantic digging, so they could ambush him with mines underground.

By comparing it with the course of the underground war at Schweidnitz, we can try to estimate the possible course of the miners' battle during the attack on Terezín.[63] By the time the third parallel was opened at the foot of the glacis, the attacker's intentions would already be well known and it would be quite clear which section of the walls he would attack. According to the ideas of the fortress designers, this would be at the protruding angles of the covered way in front of counterguard No. 21 and

[59] Ibid., pg. 469.

[60] In English, '*Dampfmine*' is called '*camouflet*' from the French word.

[61] M. de TRAUX : *Die beständige Befestigungskunst, pg. 455.*

[62] Ibid., pg. 460.

[63] For a description of the underground war at Schweidnitz between August and October 1762, see J. TIELKE, *Die drey Belagerungen und Loudonische Ersteigung der Festung Schweidnitz*, pg. 234-343.

ravelin No. 17, or in front of counterguard No. 22 and ravelin No. 18.[64] The defenders would begin digging new tunnels from listening galleries ahead of time in these places to prepare the defence.

A huge advantage is that the Terezín tunnels are intentionally built above the groundwater level, so it is impossible to dig under them (like in Schweidnitz). It is important to remember that in the 18th and 19th centuries, the level of the Ohře was significantly lower. The sluices normally only held back the water needed to drive the mill wheels. The construction of the Terezín weir in the second half of the 20th century drastically changed these conditions.

The besieger would try to estimate the location of the defenders and dig towards them to detonate his compression mine nearby. He would certainly succeed in doing so, but only after some time and several attempts, because the besiegers would fire their camouflet in his path in the tunnels dug from the listening galleries. The attacker would most likely try to advance in a line in one direction to reach the envelope level as quickly as possible, to destroy it with explosions and thereby destroy the main communication route in this section. The defenders, on the other hand, would try to hinder his advance to the side and rear with explosions.

Even the architects of Terezín had no illusions of being able to stop the advance of enemy miners, but they intended to make it as difficult as possible, making them pay dearly for every metre of underground space. Sooner or later, however, the attacker would reach the envelope and cut it off. But this did not automatically mean victory. The regular system of communication galleries still allowed the defenders access to the contested section of the envelope from both sides. Even after clearing the entire envelope, the defenders were left with a second line of defence, consisting of a communication gallery and a level 2 mine branch, from whose niches new tunnels could be dug towards the enemy and ever new mines could be laid in his path. Until the defenders were definitively expelled from a given section of the underground, the attacker could not continue his attack on the surface, as he would be exposed to the risk of destruction by underground mine explosions. The last line of defence was the main gallery itself, from which it was still possible to dig new mine tunnels. Only after its destruction or occupation could the besieger successfully complete the crowning of the covered way and consider himself master of the first line of defence — at least in some sections. At this point, however, there were essentially no mine tunnels in these places, and the surface of the glacis would resemble a lunar landscape.

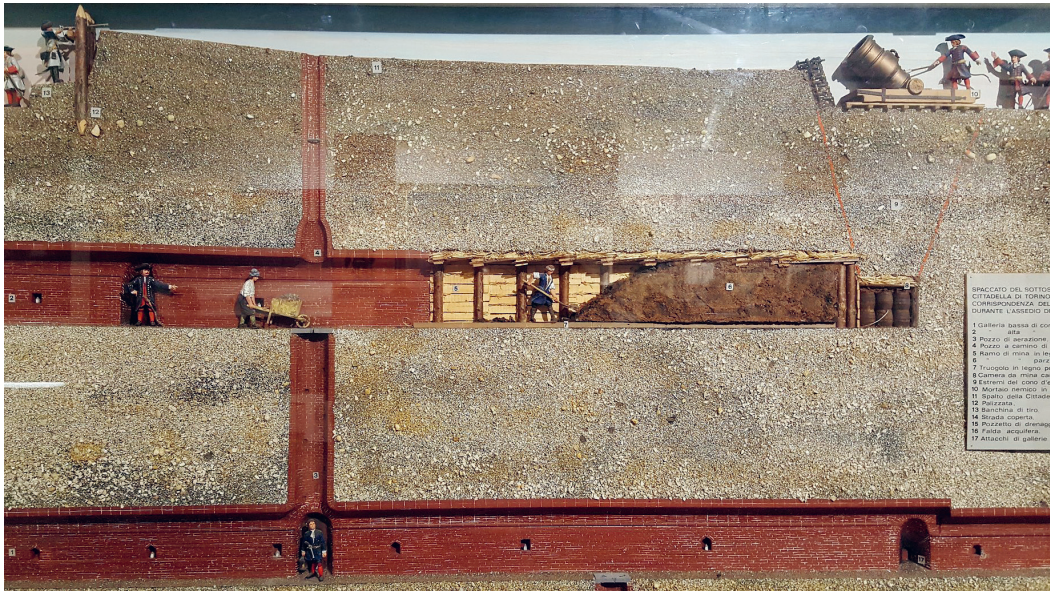
[64] J. HOFMAN, *Paměti o obraně pevnosti Terezín, pg. 119.*

This is the primary purpose of the mine system in the forefield of the fortress (under the glacis). A special variant of this is the mine system of bastions 3 and 5, which it was assumed that the enemy would attack. Their huge area of approximately 15,000 m^2 was intended for independent mining as a covered way, but on a small scale. The need to overcome its open area under fire from the defenders forced the attacker to advance again through approach trenches and dragging cannons with them, with which he would break through the last line of Terezín walls. Underground mines were also a thread here, forcing the attacker to once again engage in tunnel warfare.

However, the 'demolition mines' in the other ramparts had a slightly different function. When the enemy created a breach in the wall and his soldiers were able to get a hold of it and climb to the top, it was possible to detonate the ramp in the breach. If the attacker overcame this trap, he would then need to build a fortified position on top of the rampart and another artillery battery with which to shoot a breach in the next line of defence. Like the covered way, these enemy positions were also meant to be perfect targets for the local mines. But they also allowed something else. The relatively narrow space of the ramparts of ravelins, reduits and counterguards was impossible to blow up thanks to them. If the defenders had to retreat from somewhere, they could demolish it completely so that the attacker would have no way to catch hold of it.

It was precisely the difficulty of underground warfare and the arduousness of other mining work related to the existence of mines in Terezín that meant that no one really wanted to attack fortresses armed in this way. As Austrian military engineer de Traux wrote in his textbook immediately after the Napoleonic Wars: *'Examples of sieges using mines are so rare that after the sieges of Schweidnitz in 1762 and Valenciennes in 1793, there have been no more, because fortresses with real mines are not besieged at all.'*[65]

[65] M. de TRAUX: *Die beständige Befestigungskunst, pg. 473.*



The model illustrates a charged mine chamber (fourneau) positioned beneath the opposing mortar battery. (Museo Civico Pietro Micca e dell'Assedio di Torino del 1706).

The model illustrates a detonated mine chamber disabling a mortar battery. (Museo Civico Pietro Micca e dell'Assedio di Torino del 1706).

Mine testing

Although the mine tunnels in Terezín were never used in combat, their effectiveness was nevertheless tested during construction. It was a relatively common act that was also documented at other fortresses equipped with such an advanced defence system (Josefov, Petrovaradin).[66] First of all, it was a spectacular thing to behold, often done as members of the imperial family watched. But the purpose was also highly practical, as the experiments were carried out near the fortress in the same soil in which the mine tunnels were laid. The knowledge gained about the force and effects of the explosions was carefully recorded, and it became a guide for future miners during the expected siege.

In August 1787, test mine explosions were carried out in Terezín, which aroused interest as far away as Vienna. They took place in a location called 'Švédská šance' (Swedish Redoubt), which is located on the southern edge of the Bohušovice Inunndation, beyond the boundaries of the fortress cadastre. Wiener Zeitung wrote the following report on 18 August 1787.

'*Early in the morning of 7 and 8 August, two mines, which had been set up for testing by Colonel von Mikowini, were blown up in front of the outer elements of Terezín near the village of Bohušovice in the presence of His Imperial Highness Archduke Franz, generals and other officers, as well as a large number of people. It absolutely met all expectations. His Imperial Highness expressed his exceptional satisfaction and generously rewarded the mining company. Thanks to the good leadership of the officers, everything went smoothly*.'[67]

This is not the only source we have for this event. A drawing of the test explosions has also been preserved in the Vienna War Archives, from which we can learn more.

The explosion was carried out at a location that cannot be specified today, namely 'Švédská šance' near Bohušovice nad Ohří. The terrain was modified to look like a covered way and glacis of a fortress. Then two mine tunnels were excavated — a first-level mine 10 fathoms (approx. 3.25 m) below the surface, and a second-level mine 20 fathoms (approx. 6.5 m) deep. The charge of the first-level mine consisted of 96 pounds (approx. 54 kg) of gunpowder. The mine furnace was blocked alternately with bricks, logs about 16 cm in

[66] Cf. *Beschreibung der Minen-Experiments, welches im Monat September des 1765igsten Jahrs zu Peterwardein vorgenommen worden* [online]. Available at: https://www.manuscriptorium.com/apis/resolver-api/cs/catalog/default/detail/manuscriptorium%7CAIPDIG-VHUP___IIR_C_3672___0463RI3-cs [cit. 2025-12-06].; Olga MERTLÍKOVÁ, *Minové experimenty v pevnosti Ples (Josefov)*, Svorník, sborník příspěvků z 11. specializované konference stavebně historického průzkumu, Praha 2013, pgs. 124–127.

[67] Wiener Zeitung, 18 August 1787, pg. 1994.

diameter, and sandbags. It took 7 hours and 28 minutes to place and seal this charge. Early in the morning of 7 August at 7:00 AM, the charge was detonated with excellent results. The soil ejected by the explosion flew 20 feet (about 6.5 m) high. The crater was also 20 feet (6.5 m) in diameter, twice the line of least resistance. This exactly matched the calculations for the Terezín fortress. The crater was only about 80 cm deep after the ejected soil fell back, which would not have allowed the enemy to use it to advance against the fortress. The explosion did not damage the level 2 mine located below it at all.[68]

A level 2 mine charge was detonated a day later at the same time. It was laid 20 feet (6.5 m) deep, slightly to the side of the previous explosion. Due to this and the sandy subsoil, it consisted of only 550 pounds of gunpowder (about 308 kg), although correctly calculated, 687 pounds (about 385 kg) would normally have been used. Laying and sealing the mine took 10 hours and 22 minutes. But according to the report, this was mostly because the lamps were not burning well due to the stuffy space. This test was also a great success. Despite the reduced charge, the desired result was achieved. The crater was 39 feet (about 13 m) in diameter. The ejected soil flew 24 feet high (about 7.8 meters) and returned almost entirely to the crater, leaving only a depression about a metre wide on the surface.[69]

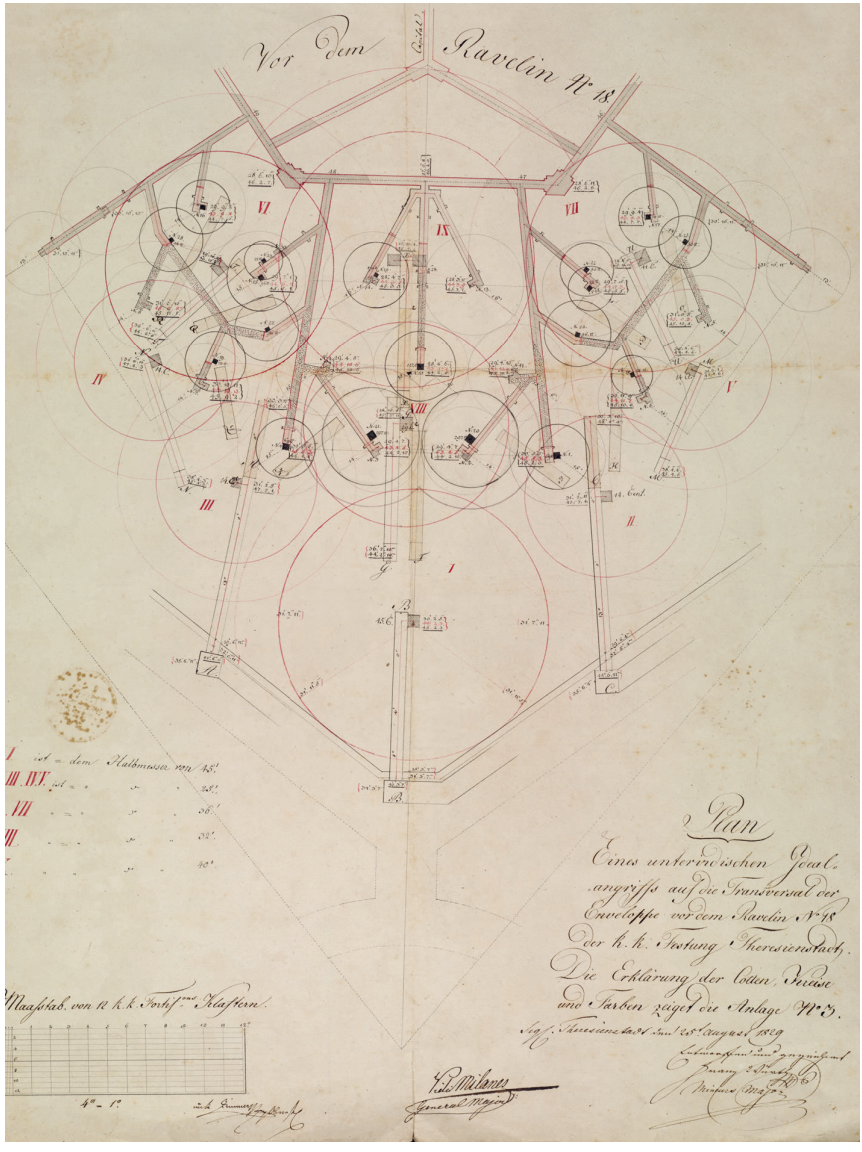
There are eyewitness accounts for both explosions, including entries in the journal of Archduke Francis, who was greatly impressed by the trials, as is evident from his slightly exaggerated account. On 7 August 1787 he wrote the following:

'*We got up at half past six, and at seven o'clock we set out through the Prague Gate to the mine intended for His Majesty. Today a small mine was to be detonated. First, we approached the loaded mine to inspect its layout, the explosive box, and everything necessary. Then we moved to a safe distance, and after the powder in the detonator was ignited, the explosion occurred. Not even seconds passed between the ignition and the explosion. First the earth rose and we heard a sound like the wind. The dirt rose in the shape of a sheaf like a storm cloud to a height of about 4 fathoms* (approx. 7.59 m — author's note)[70]. *When it fell back, a large plume of smoke was created, which quickly disappeared. The resulting funnel was irregular, and although the mine's resistance distance was only 10 feet* (about 3.16 m — author's note)

[68] Drawings of the test explosion of the mine on 7 – 8 August 1787, ÖNB, Kartensammlung (KAR), sign. FKB T.12. Ibid.: GPA Theresienstadt Alpha, 1 Planskizze samt Erklärung über die 2 Probeminen.

[69] Ibid.

[70] Unlike other places where fortification measures are clearly used, here we use the usual Upper Austrian measures for conversion.



Plan of the projected course of mine warfare during the defense of the foreground in front of ravelin No. 18 – black circles denote defenders' mines, red circles denote attacker's mines (VHA, 1829).

and it was filled with only 96 pounds of powder (about 54 kg — author's note)*, its diameter was still more than 20 feet* (about 6.32 m — author's note). *There were also entire piles of clay thrown outside the funnel, but only to a short distance of one or two feet* (31.6-63.2 cm — author's note). *The ground was sandy as dust, but completely burned around the chamber. The entire chamber and some parts of the crates were completely shattered and burned. The funnel was parabolic. It is not very deep, as most of the earth in it, about 8 feet high* (about 2.53 m — author's note)*, fell back in again. (…) The experiment went as well as it could, especially since the lower gallery, which was 10 feet from the top gallery* (approx. 3.16 m — author's note)*, suffered no damage at all.*

The detonated mine smoked heavily from the gallery for a while. An hour later, one could walk up to the first crown without smelling the smoke[71]*. The crown remained completely intact, as did the box with explosives. The cladding also suffered no noticeable damage, only one of the outermost support beams was completely deformed at the top, and the penultimate one before the crown shifted, causing several boards of formwork and some dirt to fall off the first one. However, the greatest force of the mine was directed above the opening against the breastwork, which it completely broke through.'*[72]

A day later, a report on the second explosion of a level two mine was written:

'*I got up at half past six, and at seven we headed to the mines again. We tried a level two mine. The result was the best it could be. The mine lifted the earth smoothly with no great sound, exactly to a height of 4.5 fathoms* (approx. 8.53 m — author's note)*, then everything fell down again and the funnel, which was supposed to be 20 feet deep* (approx. 6.32 m — author's note)*, filled up again to a height of 16 feet* (approx. 5.06 m— author's note), [73] *because the chamber was designed for this distance. This time we felt a fairly strong tremor as the ground opened up. The funnel was almost completely round, with the edge only slightly raised on the sides, where a small mine had exploded and the ground was slightly loosened. Because the glacis was small, some dirt fell on all 4 sides. The charge had 550 pounds of powder* (308 kg — author's note).'[74]

[71] Originally *'Krönung'* — a technical term of unspecified meaning. It is used in connection with the sealing of a mine ('*the mine was sealed with 3 crowns*' etc.)

[72] Österreichisches Staatsarchiv, Haus-, Hof – und Staatsarchiv, Habsburgisch-Lotringische Hausarchive,Hausarchiv, Handarchiv Kaiser Franz I., kart. 14, 14-1 „Journal meiner in Böhmen 1787 gemachten Reise", verfasst von Erzherzog Franz von Toskana, fol. 59v.

[73] The two last dimensions are originally listed in fathoms, but this must be a scribe's error. According to the plans, it should be 20 and 16 feet, respectively, and not fathoms.

[74] Ibid, fol. 60r.

Plan of the 1787 mine experiments in Terezín, illustrating the results of **level 1 and 2 mine branches** detonations (Österreichische Nationalbibliothek).

Next construction stage

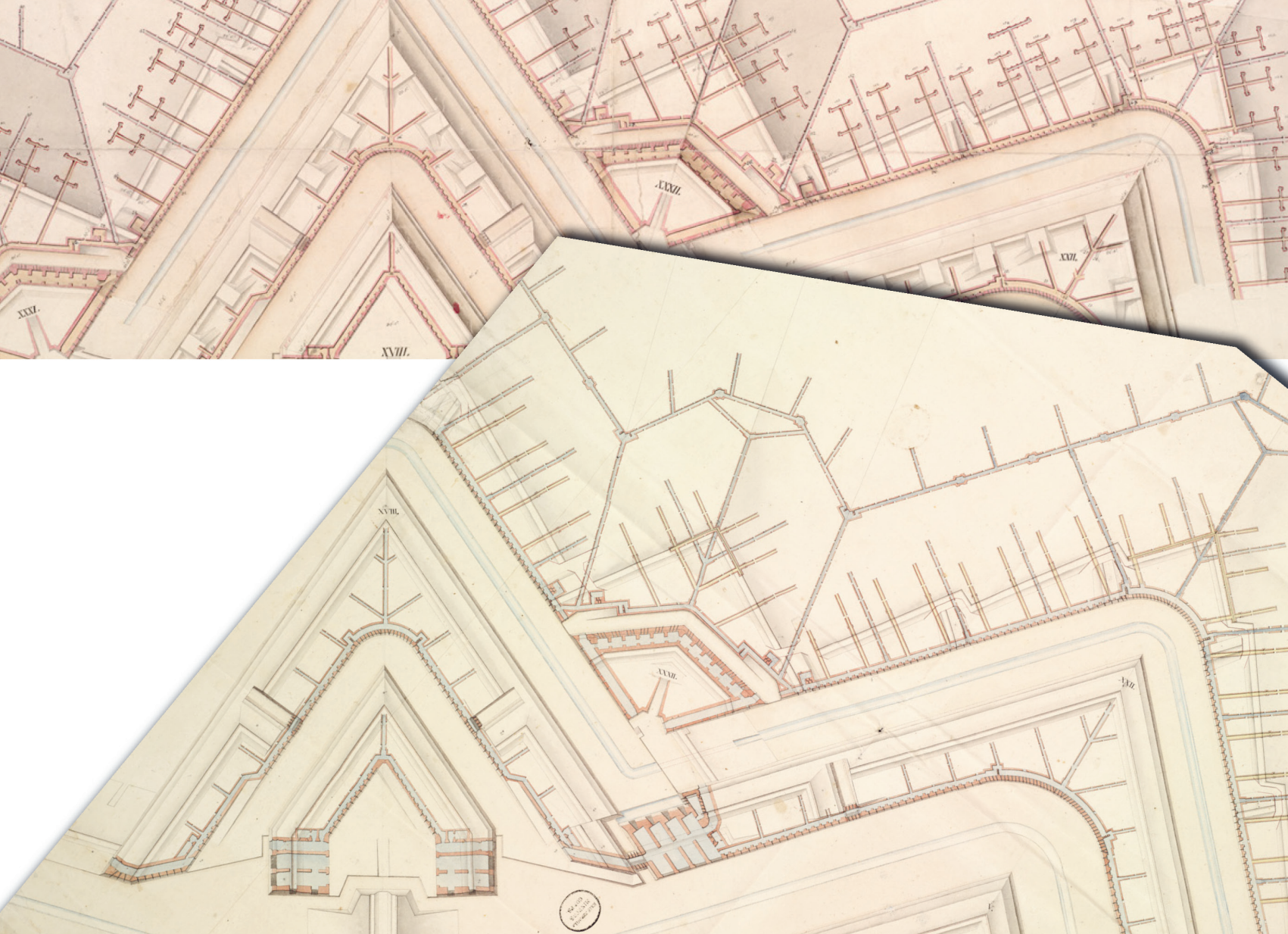
The oldest version of the mine system did not remain unchanged for long. Sometime before 1809, the listening galleries were extended and the mine tunnels of the Main Fortress were branched. This is how the Terezín underground was shaped into its current form. We don't know much about this work, we only know that it happened. The corridors were extended through mining with timbering, into which the brick structure of the mine was built. Even today, we can easily identify the extensions of the listening gallery; there are no protruding foundation walls and they are only covered with one layer of plaster (older corridors have a double layer). The transition between older and newer plaster is clearly visible in many places. In the years 1809 to 1810, work must have already been underway, because we have a record of the brickwork of listening gallery No. 47, while other work was to be stopped for the time being due to a lack of funds.[75] In the following year of 1811, these activities were completely stopped for the same reason.[76] There is a mention of captain Franz Würth von Hartmühl in 1812, who had already participated in experimental explosions with Březina as a 'Jung-Mineur' in 1787 and had now returned to Terezín.[77] His obituary says the following: '*In 1812 he was appointed captain and received the order to add missing branches to the Terezín mine system* (e.g. 'Wendungen' — author's note). *He had only 140 men, miners, at his disposal, 74 of whom were recruits. Nevertheless, with unprecedented diligence and endless effort, he managed to complete the mining in an even shorter than expected time of 3 months. In a length of 1,800 fathoms, in the sandy subsoil, he proceeded by mining with timbering, which was later bricked up.*' [78] However, there is also a record in literature for years 1814-15 '*according to the plan submitted by mining captain Schirr, the mine corridors that were currently supported by timbering were bricked up*.' This completion of the mine system therefore lasted at least from 1809 till 1815. The author of the project was most likely captain

[75] Military Historical Archives Prague, General Command Prague (Generalkommando zu Prag) 1723-1882, card 106, file 1810–243.

[76] Ibid., card 115, file 1811-64.

[77] *Gehorsamste Bemerkung über die eingesender werdenden Plans und Schriften*, Governor Franz Würth in Terezín 21 August 1828, Plans Collection Terezín, III K 29.

[78] *Franz Würth Edler von Hartmühl, k. k. Oberst* (Obituary), Östreichische militärische Zeitschrift 1865, volume 1, pg. 335-336 [online]. Available at: https://www.google.cz/books/edition/%C3%96streichische_milit%C3%A4rische_Zeitschrift/DdhaS7nIzqUC?hl=cs&gbpv=0 [cit. 2025-12-09].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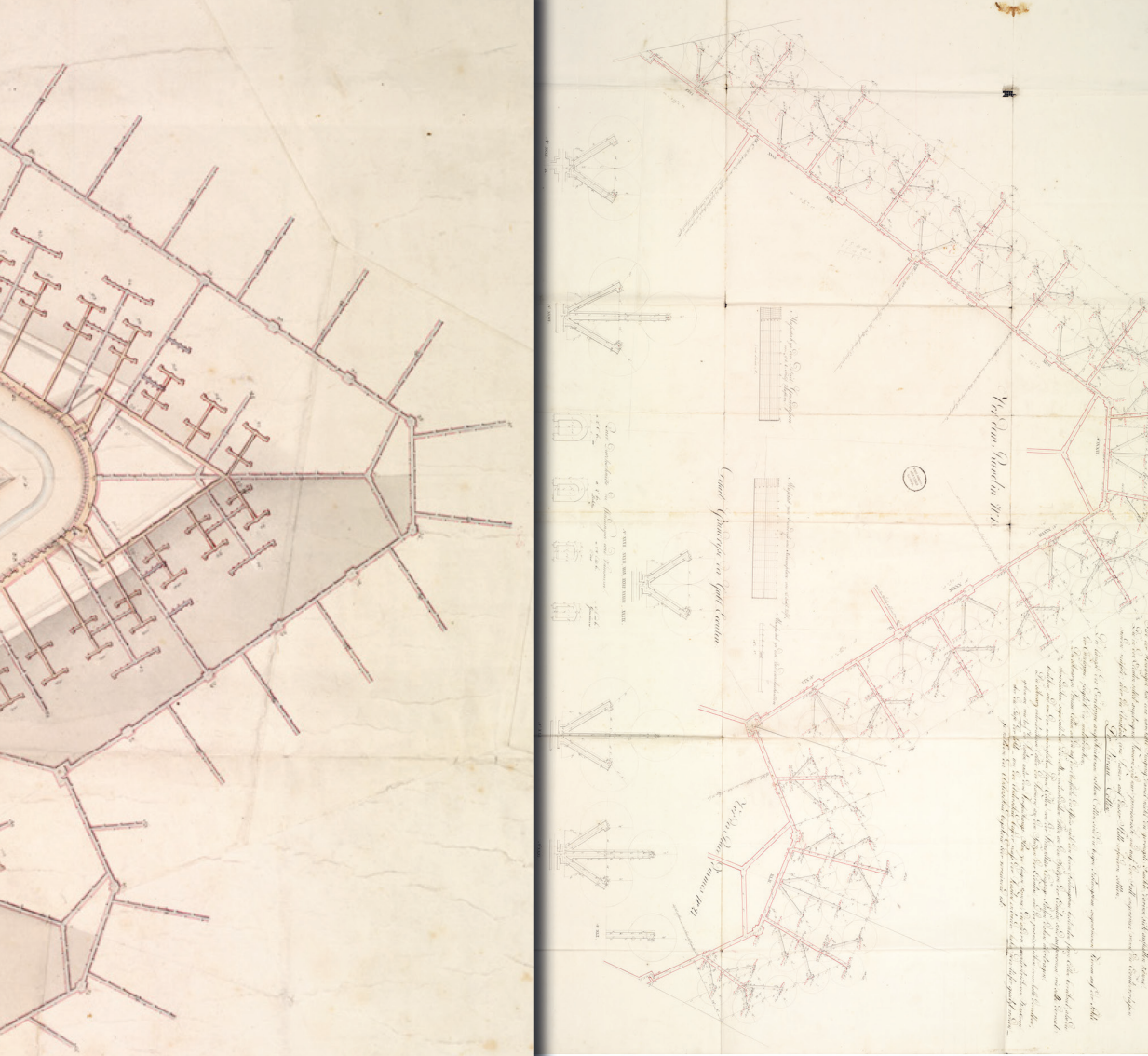


The structural evolution of the Terezín fortress mine system – left: the earliest phase; center: expansion during the early 19th century; right: an unrealized proposal to supplement the listening galleries with mine branches (VHA).

Schier, mentioned in Terezín as early as 1805.[79] The work itself, or at least some of it, was later performed by captain Würth.

No more changes were made to the local mine system. A series of detailed proposals for expanding the envelope and listening galleries from the 1820s written by captain Würth have been preserved,[80] but it never happened. There were many reasons for this: state bankruptcy and the monarchy's depletion after the Napoleonic Wars, the need to renovate other more important structures, and last but not least, the floods.

In March 1821, another flood arrived, with the Elbe reaching almost 4 metres above its normal level, and then again in 1824. And there were more to come. Although more detailed information for Terezín is lacking, we can add the years 1835 and 1845, which is evidenced by stones with the inscription '*Rep*' and the year in the fortifications.[81] The preserved plans for underground repairs after flood damage most likely relate to these events. And the damage was truly substantial. In 1821, the water caused the collapse of part of the envelope and the listening gallery under the road in front of the left face of counterguard No. 21.[82]

We have an extensive report concerning 1827 and repair plans by captain Würth concerning dating back a year before. The surface excavations had to be repaired and extensive sections of the corridors re-walled, specifically level 1 mine branches No. 5, 9, 10, 23, 25, 77, 82, 93, 105 and 126, level 2 mine branch No. 44, and listening galleries No. 33 and 63.[83] In 1829, the cracked vault and masonry of the main gallery in front of the left face of ravelin No. 19 were repaired; the vault had to be dug up and completely re-walled.[84] Coincidentally, the same place had to be walled over again after the floods of 2013. A year later (1830), the mine system of the Small Fortress was installed. In the period from 1830 to 1833, repairs were performed on mine branches No. 1-5, 8-10, 12-17, 19, 22, 25-26, 43-44, level 2 mine branches No. 7-9, 17, 29, listening gallery No. 12 and 14, top gallery No. 6, communication gallery No. 1, capitals No. 3 and 7, and the

79 Terezín fortress plans, plan III K/29.

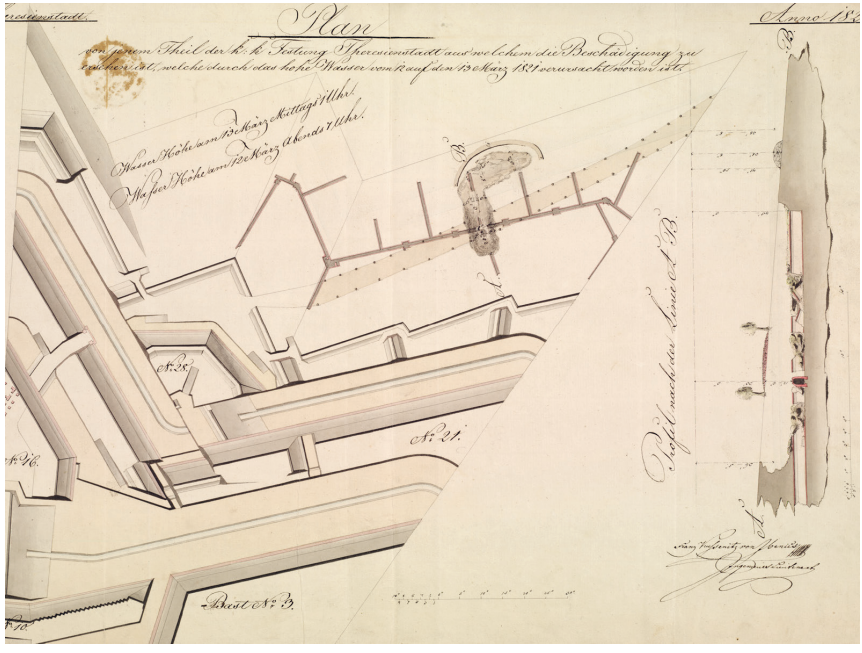
80 Ibid., plan III K/05 and plan III K/06.

81 Rudolf BRÁZDIL et al., *Historické a současné povodně v České republice*, Blansko 2005.

82 Terezín fortress plans, plan III 1/054.

83 Ibid., plan II K-H/y 23,28.

84 Ibid., plan III K/32.



Plan of damage to the mine galleries in the foreground of counterguard No. 21 during the floods of March 1821. (VHA).

main gallery before the left face of ravelin No. 7 and bastion No. 2.[85] Then repairs moved back to the Main Fortress. Between 1832 and 1835, it was necessary to repair and rebuild level 1 mine branches No. 4, 15, 17, 21, 25, 31, 34, 36, 69, 74, 75, 76, 79, 87, 94, 101, 103, 119, 122, 124, upper gallery No. 3 and listening galleries No. 10, 12, 18, 21, 32.[86] As this rather dry list of tunnels shows, the extent of the damage was indeed considerable. Many parts of the system also had to be rebuilt for the third time.

The nature of the flood damage to the mine system is further detailed in the report from 1847, which followed the great flood of 1845. '*Experience has shown that damage to galleries is not immediately apparent after the water recedes, it only becomes apparent after one, two or even three years, which we have also seen after the recent floods. It is not uncommon for the pavement to sink 1 foot* (32.5 cm — author's note) *two years after a flood. This is because tiles and bricks retain moisture for so long that they hold together as if they were glued, but as they gradually dry out, they lose their load and often sink a foot down. The same is true for niches, which are either pushed out or collapse, followed by sand spilling out. This happens because the otherwise dry sand, with which the masonry of the Main Fortress system is mostly covered, remains moist and solid after the water drains away. In some places, it is significantly caved in and the resulting empty spaces only fill in when it regains its original dryness. As a result, the dry sand presses down on the masonry with full force, pushing out the dry-laid niches and then rolling out at a 45° angle into the tunnel. Because this has to be cleared from the gallery, empty spaces are created under the layer of soil forming the glacis, depending on the amount of sand that pours out. After rains, when the soil is fluffed up, it sinks into these empty spaces, often creating large depressions on the surface that must be filled with good soil. In the fort, on the other hand, niches very rarely collapse because the sand with which the mine system is covered never dries out. This is why no empty space and depression can form between the sand and the glacis soil layer. Damage to the main gallery of the fort in front of the right face of bastion 2 along the road leading from Prague to the fortress, which could result in the collapse of the retaining walls 80 fathoms long* (approx. 156 m — author's note)*, was repaired this year. In addition, the damaged tip of mine branch 3 near the fort in the length of one fathom and three feet* (approx. 3 m — author's note) *was taken down and rebuilt. The following work was performed in 1847: in counterguard 21, demolition mine 3, 5 fathoms long (approx. 9.75 m — author's note), is so damaged that it may collapse, so its demolition and reconstruction is planned*

[85] Ibid., plans II K-H/z18a, II K-H/z18a, II K-H/z26, II K-H/z24 and II K-H/z20.

[86] Ibid., plans II K-H/z55, II K-H/z57 and II K-H/z66.

for 1847. Level 2 mine branch 42 in front of the Main Fortress, the first branch on the right in the chamber itself and one fathom back, is also at risk of collapse, so it is urgently scheduled for repair in 1847.' This description can also explain the damage after the last floods of 2002 and 2013. [87]

The last detailed description of flood damage repairs in the fortress era is from May and June of 1849, probably after the flood in 1845. At that time, repairs were performed on the brick walls of the niches in listening galleries No. 37, 47, 61 and 63, and level 2 mine branches No. 29 and 32, and 11 in the fort. The cracked vault of listening galleries No. 12 and 33 and level 2 mine branches No. 30 and 44, namely at the fort of level 1 mine branches No 24-26, 40, 43 and 63, were also repaired.[88]

We don't have any information about other later damages in either the planning or the file documentation.[89] The mine system entered the war of 1866 in good and fully functional condition: *'Because the galleries have been well cared for since their construction, they are in perfect condition and completely dry throughout. Only when the inundation was filled, water 8 inches* (approx. 20 cm — author's note) *deep appeared in some parts of the main and connecting galleries.'*[90] We can only speculate whether and how it was affected by the great flood in the following years. The tunnels were certainly damaged in 1920, when the embankment at the foot of the inundation could not withstand the onslaught of the flood and water poured through it into the tunnels and further into the fortification system.[91] Similarly, in 1940, part of the demibastion collapsed at the Small Fortress and water reached the underground.[92] The last stage consisted in extensive repairs after the floods of 2002 and 2013, but these would call for a separate article.

87 KA, Mittelbehörden, Geniewesen, Geniehauptamt, Akten, karton 222, file 1847-5-9.

88 Military Historical Archives Prague, Military Construction Offices, FDD Prague, card 7, Baurapport for May 1849 and Baurapport for June 1849.

89 However, we should also take into account that the extensive and still unprocessed archive of the Terezín Genie-Direction with hundreds of boxes has not yet been systematically examined.

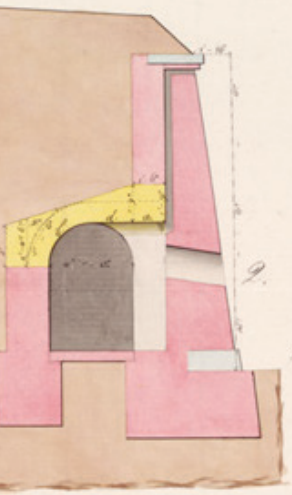
90 GPA Theresienstadt Nr. 15, Gov. Eisenbach's report from 12 September 1866.

91 SOA Litoměřice — Lovosice, Královec Alois collection, box 34, natural disasters.

92 Ibid.

Repair of the main gallery in front of ravelin No. 7 of the Small Fortress in 1830. (VHA).

h der Linie AB. Profil nach der Linie CD.



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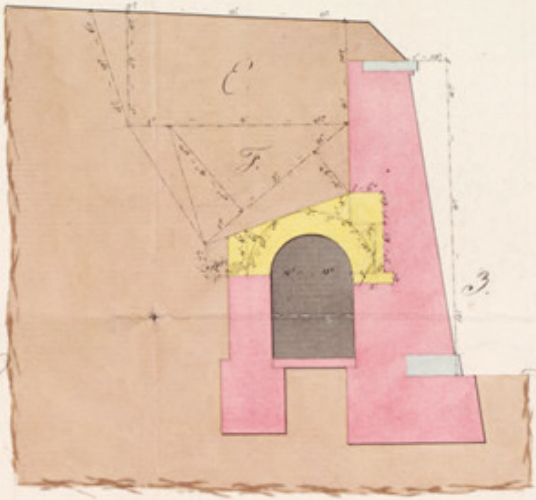
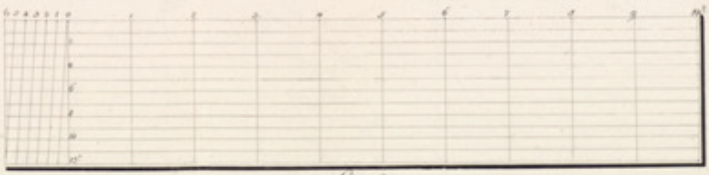
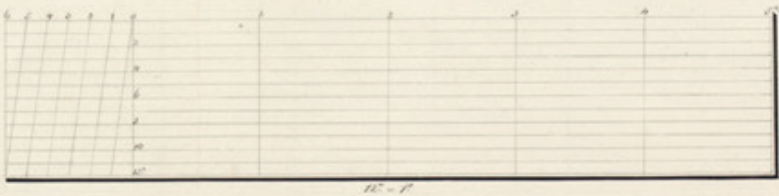


Maßstab für den Grundriß.



Maßstab für die Profile



Tunnel issues

• How do you evaluate a technical monument that was never intended to survive more than two centuries? It is an exceptionally extensive and unique system, the current state of which is influenced by two opposing factors — nature and man. Both can do harm, but they can also help.

If we start with the latter, i.e. man, or rather the human factor, we can distinguish several subgroups.

The first of these is the factor of the military engineers of the time. In their effort for the most efficient construction process, they chose the logical option of building from the envelope towards the main gallery. Overall, there was nothing unusual about this — the procedure was based on the absence of defined vertical levels and volumes in the main moat, the minimal need for embankments in the area of the glacis bases, and also the requirement for potential combat usability of individual sections during construction.

However, this procedure resulted in a problem that became apparent when the communication tunnels and mine branch arms were connected to the main gallery. This structural continuity created expansion planes, the effects of which are still visible today. If the construction of the counterscarp itself were not problematic, this would be a negligible phenomenon — expansion joints would even be welcome here. But reality is more complicated.

The main problem with counterscarps is their structural design, from the foundation itself, through the staging and connection of the main gallery, to the thickness of the backfill. If we approach it gradually, we will find that the 17-foot (5.5 m — authors' note) retaining wall of the counterscarp is founded in sandy loam soils typical of the Ohře floodplain. Everything above the original terrain level consists of backfill layers created during excavations; other deposits are common, often unsystematic anthropogenic soils.

The depth of the foundation is usually between 1.0 and 1.3 m, whereas the foundations have one to two-stage offsets of 0.24 m each. Given the high occurrence of fluctuating groundwater levels and the fact that the counterscarps were founded approximately 3.6 m below the original terrain level before the construction of the fortress, as well as the fact that they were repeatedly exposed to both floods and test flooding of the fortification trenches throughout the fortress's existence, it is obvious that the structure had to withstand variable hydrostatic and earth loads over a long period of time.

It is necessary to take into account that there are small, but real movements in the foundation joint of the counterscarp — due to changing water conditions and the nature of the subsoil. It is no coincidence that Terezín is classified as a 'water' fortress.

The exility of the counterscarps is more problematic than the foundation itself. This can be categorized into two basic sections. The first are the arched walls in the capitals. The main mass here consists of a wall with a constant width of 3 feet (0.975 m — authors' note), to which an inclined face plane with a base of 1 foot 11 inches (0.622 m — authors' note) is connected. This sloping face connects to the main wall in a cornice, which is located at a height of 17 feet from the plinth plane (5.525 m — authors' note).

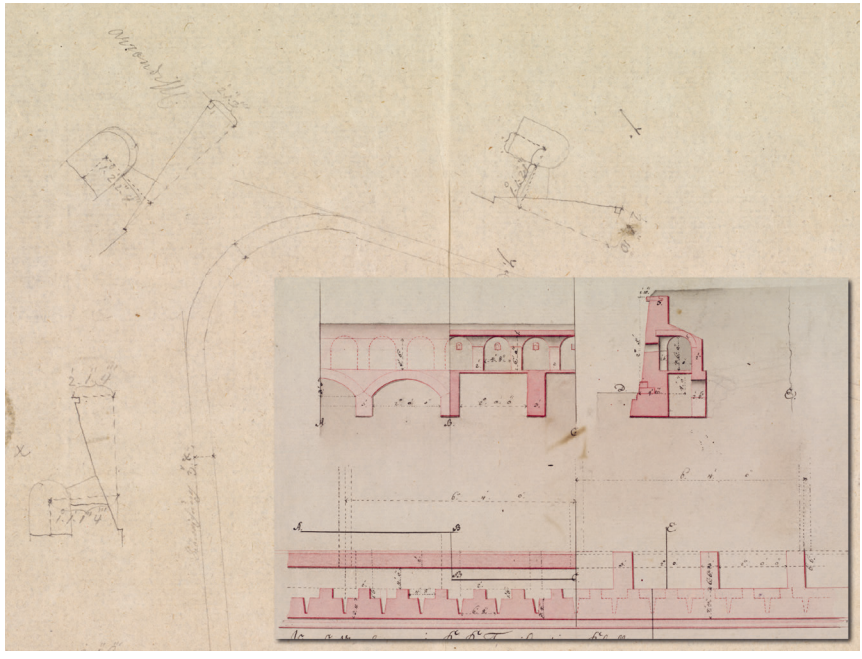
At a height of approximately 1.3 m, the main gallery is attached from the reverse side. Its loopholes do not fundamentally disrupt the mass of the masonry, apart from the holes themselves and ventilation chimneys. The corridor, which is 1 fathom wide (1.95 m — authors' note), has a back wall with separate foundations, usually laid to the depth of the counterscarp foundations. The thickness of the back wall is 2 feet (0.65 m — authors' note) and the height from the floor to the base of the vault is 1.3 m. The barrel vault is vaulted both into the back wall — which is partly stabilised by the original terrain and partly by the backfilled soil — and primarily into the mass of the counterscarp wall, in the full profile of the masonry. Above it is a lean to roof with sloping from the counterscarp towards the terrain.

The construction itself took place in stages here. In the first stage, the counterscarp wall was erected to the level of the base of the vault of the main gallery, which approximately corresponded to the lintel of the loopholes. The second stage, which was almost simultaneous with the first, included the construction of the back wall of the main gallery up to the base of the vault. In the third stage, a barrel vault was constructed, and in the last stage, the remaining part of the escarpment wall was extended up to the crown.

This structural design — additionally reinforced in this section with a concave, massive wall — does not show any significant signs of degradation or structural damage. The condition is significantly more favourable in this respect than in the larger sections of the main galleries, which will be described below.

The second section, where the fragility is more pronounced, is the main gallery in straight sections of the counterscarp. The main mass of the wall is also 3 feet wide here (0.975 m — authors' note), extended by an inclined face with a base of 1 foot 11 inches (0.622 m — authors' note), which connects to the main mass of masonry at a height of 17 feet, i.e. at the level of the counterscarp cornice (5.525 m — authors' note).

However, the difference lies in the shooting posts. They consist in niches 4 feet 8 inches wide (1.516 m — authors' note), 1 foot 6 inches deep



Preliminary sketch and design for the main gallery
in the Terezín fortress (VHA, undated – 1780s).

(0.487 m — authors' note) and vaulted by a low vault only 4 feet (1.3 m — authors' note) high. The niches are spaced regularly, with an approximate distance of 2 feet (0.65 m — authors' note) between them. These niches are in the main mass of the counterscarp wall and they significantly weaken it — sometimes taking up half its original thickness.

The cross-section of the counterscarp wall is as follows: from the base of the plinth to the floor of the tunnel (approx. 1.3 m) it has its full thickness, as in the first described section, but from this level onwards, its mass is dramatically reduced. The original thickness of 1.597 m is suddenly reduced to 0.975 m, and remains this way until the height of the vault face (1.95 m), where the thickness is only 0.694 m. Above this level, the remaining part of the counterscarp wall begins with a height of 2.28 m, which has a thickness of 0.975 m at the crown, but it is situated in a section formed by backfills with inhomogeneous compaction and fraction. Moreover, the main gallery's own mass also leans against this weakened structure — and not always in an appropriate way.

The construction stages were the same as described in the previous section. In the first stage, the counterscarp wall was erected to the level of the base of the vault of the main gallery, which approximately corresponded to the lintel of the loopholes. The second stage, which was partly simultaneous, included the construction of the back wall of the gallery up to the base of the vault. In the third stage, the barrel vault of the main gallery was built, including the vaulting of the niches, and in the last stage, the remaining part of the escarpment wall was completed to the height of the crown.

In this straight section, the profile of the main gallery was narrower, only 4 feet (1.3 m — authors' note), with a steady height of 1 fathom (1.95 m — authors' note). The back wall of the gallery was 2 feet thick (0.65 m — authors' note). The gallery vault, like the niche vaults, was only vaulted into narrow pillars between the niches, creating an extremely overloaded static element that is also one of the biggest problems of the entire system today.

The inappropriately designed lean to roof above the vault also significantly contributes to the overload, transferring the pressure of the soil directly to the structurally weakest parts. All straight sections of main galleries suffer from this shear load. The result is the systematic tearing away of entire structural segments and adjacent ramparts of the Terezín fortress.

If we move to other parts of the underground, the profiles of which were described at the beginning of this text, we will also encounter a number of recurring problematic elements. One of the most striking are more recent changes, which, without knowledge of the context and without re-

spect for the construction logic of the galleries, disrupt their technical and operational stability — typical examples are sewerage pipes from regular homes, foundations of modern buildings, and other unprofessional interventions.

Another factor in the degradation is human activity, namely theft of the original brick paving stones. In addition to their function of draining water from the underground, these also had a static significance — they functioned as spacer elements in the base of the gallery walls. Their removal made these areas much more susceptible to deformation.

We should also mention tree avenues and other vegetation planted above the underground tunnels. Over the years, the root systems of these trees grow into underground spaces and disrupt the vaulted structures. Although the trees get the nutrients they need from them, they tear the structures linearly and often very vigorously.

The composition of the structural parts of the galleries is also a significant factor. In sections where the tunnels passed through natural terrain without significant interference with the original soil and where there is almost no artificial backfill behind the gallery walls, there has been no significant degradation to this day. However, the situation is different in places where the vaults were created above the original terrain level and were subsequently backfilled, as well as in sections of tunnels that were later excavated. In these areas, significant technical problems have been occurring since the first floods, sometimes leading to the collapse of the arches.

Although mining textbooks repeatedly emphasize that excavated tunnels are not suitable due to the laboriousness and, above all, the exility of the structures in relation to the earth load, this lesson is generally applicable and clearly corresponds to the situation in Terezín.

These faults are mostly due to two complementary factors. The first is the continuous subsidence of the embankments, which is still visible today — e.g. in parts of the gallery niches, often clogged with spoil tips, the deformation is quite obvious. The second factor consists in hydrostatic and mechanical changes during floods, which cause significant changes in earth pressures. The fills behave differently from the vegetated terrain: they exhibit greater expansion and a different degree of cohesion, and they react completely differently to the presence of the water column, which leads to sudden and uneven pressures acting on the vaulted areas.

As a result, the vaulted sections and sections situated in purely load-bearing zones most often collapse. These parts are repaired after every major flood — and similar failures have become an almost expected phenomenon nowadays.

As mentioned, the recurring floods that have hit the fortress throughout history are extremely burdensome for the entire fortress system — and especially its underground spaces. In many cases, the tunnels are flooded to the full height of the profile, which leads to their rapid, significant degradation. It would be desirable to limit the inflow of flood waters into the galleries, but given the town's current flood control plan and the technical condition of entrances and passages, this is not within human or technical capabilities.

Although underground passages are currently being repaired after recent floods, we should mention one more significant factor that further worsens their condition. The physical and static phenomena described above cannot be changed, but their effect is amplified by vibrations from surface transport — especially in sections adjacent to the roads at the Litoměřice and Bohušovice Gates. It is here that even newly repaired parts of the underground degrade very quickly, as vibrations disrupt the vaults, fillings and repaired masonry.

Last but not least, there is a lack of regular and systematic maintenance by the owner, who should continuously replenish fallen bricks, re-grout the necessary sections, monitor the extent and development of defects, limit recent, uncontrolled entrances to the galleries (e.g. sewer drains or foundation structures), remove vegetation root systems, remove collapsed parts of niches and repair them with suitable new materials, and fulfil the function of floor spacers and stabilisation layers. It is also essential to create a detailed asset registry of the entire system and a subsequent schedule of regular maintenance and planned repairs.

Following modern floods, several galleries collapsed and were slated for reconstruction. These incidents have provided valuable insights into the original construction principles, stratigraphy, and building techniques. This section illustrates both the construction and repair process via open-cut excavation. Repair of the collapsed main gallery following the 2013 floods using surface excavation (J. Hofman).

Restoration of a **level 1 mine branches** during repairs following the 2013 flood (J. Hofman).

Surrounding soil collapsed through the missing masonry infills of the recesses into the mine galleries during the 2013 floods (R. Gazsi).

Galleries are susceptible to pressure fluctuations from various external factors, leading to recurring defects that can result in structural collapse – repair of a **level 1 mine branches** following the 2013 floods (J. Hofman).

Conclusion

The analysis of the development of the Terezín underground counter-mine system clearly demonstrates that its current form is the result of a multi-stage construction genesis that reflected both the fortification principles of the time and the specific conditions of the location. The oldest part in the forefield of the fortress was completed in 1783, but it was largely destroyed by floods a year later. This is why a large part had to be rebuilt from scratch. But work continued even after the completion of Terezín in 1790. Only the extension of the listening galleries and the expansion of the mine branches with chambers were carried out. This alone added approximately 3.5 kilometres to the system. The necessary repairs and maintenance of the corridors — especially after damage caused by floods — were even more significant. To this day, the individual stages of construction determine both the morphology of the system and its current static behaviour. Different technological procedures used in different parts of the complex are now reflected in the varying levels of structural stability; the most vulnerable sections are backfilled sections above the original terrain level.

From a structural and functional point of view, the Terezín system is a unique system of European significance. Its elaborate structure, incorporating all the fully developed elements of an underground counter-mine system of the 18th and 19th centuries, reflects the peak stage of development of fortification engineering of this period. The concept follows the most important European schools of mining, and the Terezín system is not only an example of the application of the theories of the time (Vauban, Belidor, Schröder), it also develops these concepts further with its vastness and complexity. In the context of Central European fortifications, this is exceptionally valuable proof of the technological adaptability of the Habsburg fortification school.

These facts also underline the monumental and technical/historical significance of the system. The Terezín underground system is a unique material testimony to the development of military construction, but also a specific document on the concept of the defence of northern Bohemia after the loss of Silesia and Kłodzko. However, its value is threatened by accumulated degradation phenomena: subsidence of fills, hydrostatic changes caused by floods, destructive effects of vegetation and vibrations from surface transport, a number of unprofessional recent interventions and, last but not least, neglected maintenance. Preserving the system is therefore not just a matter of random maintenance or emergency repairs, it requires comprehensive, methodical and long-term planned intervention, along with a detailed asset registry and coordinated care for individual structural units. This is the only way to ensure that this extraordinary engineering complex, significant technical monument and exceptional example of European fortification architecture, is preserved for future generations.

Underground mine tunnels of the Terezín fortress — history, functions, problems

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