THE SITE FOR THE DEEP GEOLOGICAL REPOSITORY

Nagra's Proposal

nagra.

The purpose of the present report prepared by the National Cooperative for the Disposal of Radioactive Waste (Nagra) is to provide information about the siting proposal for the deep geological repository in Switzerland and about the associated facilities at the surface. Over the next two years, Nagra will prepare the general licence applications and supporting technical documents, including a detailed report on the site selection, and plans to submit these to the Federal Government in 2024. The authorities will review Nagra's siting proposal based on the submitted documentation.

The actors involved in the site selection process have agreed that Nagra should communicate its proposal as transparently and early as possible and not wait until the submission of the licence applications. Nagra will collaborate with the affected regions and cantons to prepare the general licence applications and plan the surface facilities. The present report is addressed to all parties involved on a regional and cantonal level as well as to the interested public. The technical-scientific data basis upon which this report is based is available in the form of supplemental QR codes.

SUMMARY

SAFETY FOR FUTURE GENERATIONS

Dear Readers

With our siting proposal, we have reached an important milestone in our project of the century of deep geological disposal. In Nördlich Lägern, the rock deep below the surface has the best long-term containment capacity for the radioactive waste and is therefore the safest site for a deep geological repository. This is where we will start repository construction once the general licences have been granted. The associated encapsulation plants will be built at the interim storage facility in Würenlingen.

We take pride in our work of the past years and decades. We have laid a solid scientific foundation: Switzerland has a safe concept, an ideal rock, and now we are proposing the most suitable site.

Whether our work and our siting proposal are sufficiently convincing will be judged by the Federal Council, Parliament and, in case of an optional referendum, by the Swiss voters. Nagra thus makes the proposals, but politicians and society make the decisions. We understand that we bear great responsibility in this challenging task of national importance and we approach this mission with great respect.

While we are proud of our achievements to date, we are aware that the deep geological repository will be constructed in a region where people live and work. Even though the purpose of deep geological disposal is to protect humans and the environment, no one wants a repository in their neighbourhood. Our proposal directly affects the siting communities and Cantons Zürich and Aargau. This raises many questions and concerns in the regions, possibly also anger and fear – and we will keep this in mind at all times.

A lot of time will pass before we start construction. We want to use these years to further develop the project in collaboration with the regions and the cantons. Many issues can only be resolved by working together. Dialogue and collaboration with the affected people will become even more important to us than they already are.

We want to solve the issue of radioactive waste disposal now, instead of burdening future generations with it – and we want to solve it together with you. We look forward to this collaboration.

Sincerely

Matthias Braun

"We want to solve the issue of radioactive waste disposal now, instead of burdening future generations with it – and we want to solve it together with you."

MATTHIAS BRAUN, CEO OF NAGRA

WHAT IS AT ISSUE?

1 THE TASK

This is a national task: the long-term, safe disposal of radioactive waste in Switzerland. Most of the waste is produced by the nuclear power plants but some arises from applications in medicine, industry and research. Today, most of the waste is being held at the Zwilag interim storage facility in Würenlingen. Nagra has been working on a dependable, safe solution for decades.

2 THE SOLUTION

Experts world-wide agree: a deep geological repository is the safest option for the long-term disposal of radioactive waste. For this reason, this solution is anchored in Swiss legislation. A deep geological repository consists of drifts and caverns located deep underground. Engineered barriers such as steel canisters and geological barriers such as rock formations enclose the waste over a very long time period. The most important barrier is the tight rock in which the repository will be constructed, i.e. the host rock. In Switzerland, the Opalinus Clay is most suitable as a host rock.

3 THE SEARCH FOR A SITE

The Federal Government has had the lead in the site selection process since 2008. Starting with the whole of Switzerland, less suitable regions and rock formations were excluded in a multistage process. In 2018, the Federal Council determined that Nagra should investigate three regions in greater detail: Jura Ost, Nördlich Lägern and Zürich Nordost. Nagra has carried out this work and is therefore now in a position to propose the site for a deep geological repository.

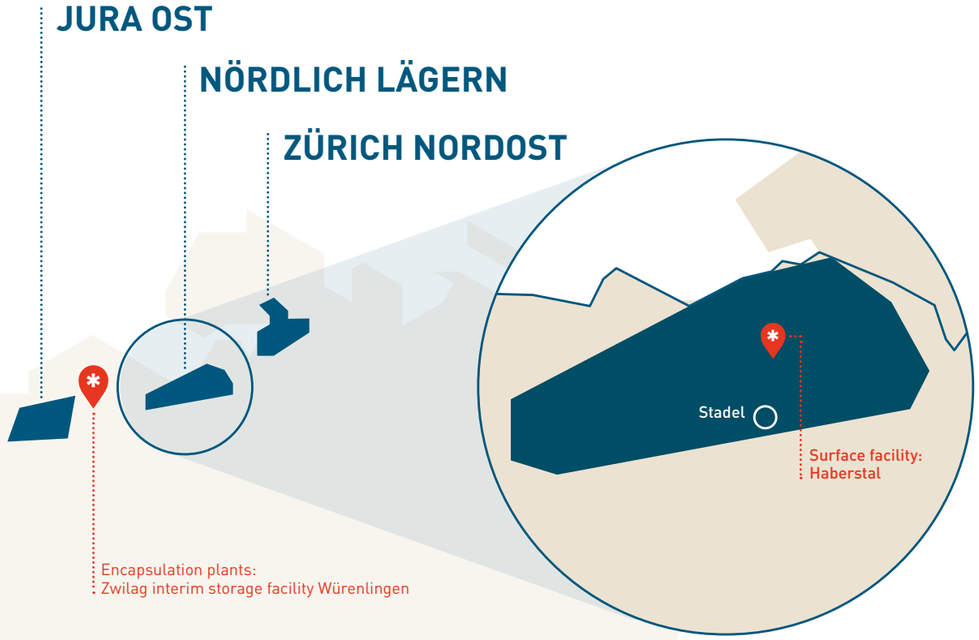
4 THE SITING PROPOSAL

Nördlich Lägern has the largest safety reserves and is, in Nagra's opinion, the most suitable site for a deep geological repository for all of Switzerland's radioactive waste. The rock in Nördlich Lägern has the best containment capacity to enclose the waste – today and far into the future. In addition, it provides the largest flexibility for the layout of the repository. The legally prescribed dose limits cannot only be met but doses will be significantly lower – by orders of magnitude.

Based on the region's recommendation and following Canton Zürich's supporting statement, Nagra has determined the site for the surface facility: the Haberstal area in the community of Stadel. The encapsulations plants for the waste are to be constructed at the Zwilag interim storage facility in the community of Würenlingen.

5 THE NEXT STAGE

The scientific and technical foundations have been developed and Nagra will now prepare the general licence applications and submit these to the Federal Government around two years from now. The Swiss Federal Nuclear Safety Inspectorate and other experts will review the applications. Based on this, the Federal Council will make its decision, followed by the Swiss Parliament and, in case of a referendum, the Swiss voters. The waste producers are responsible for financing the disposal of the radioactive waste; this has been secured by the Decommissioning and Waste Disposal Funds. Today, an important milestone has been reached: now that a long research and development phase as well as the site selection process have been completed, the next phase of licensing and implementation can begin. Nagra is convinced that a project of this dimension requires the support of everyone involved – society, the scientific community, economy and politics.



NÖRDLICH LÄGERN: THE BEST SITE WITH THE LARGEST SAFETY RESERVES

NAGRA'S SITING PROPOSAL: NÖRDLICH LÄGERN

Nagra's investigations show that Nördlich Lägern best meets the requirements on quality, stability and flexibility. For this reason, this site is the most suitable.

All three siting regions fulfil the requirements for the construction of a repository, but the Nördlich Lägern siting region is the most suitable. Nagra has investigated the three regions based on regulatory requirements and has identified three relevant differences that are decisive in selecting the site:

Quality of the geological barrier: A large distance between the Opalinus Clay and the nearest water-bearing rock layer contributes to the containment of the waste. In addition, ancient porewater in the Opalinus Clay, i.e. porewater that has been enclosed in the rock over a very long time, indicates a highly effective containment capacity – in other words, a good barrier. The Opalinus Clay in Nördlich Lägern has the greatest distance to the nearest water-bearing rock layer and the oldest porewater.

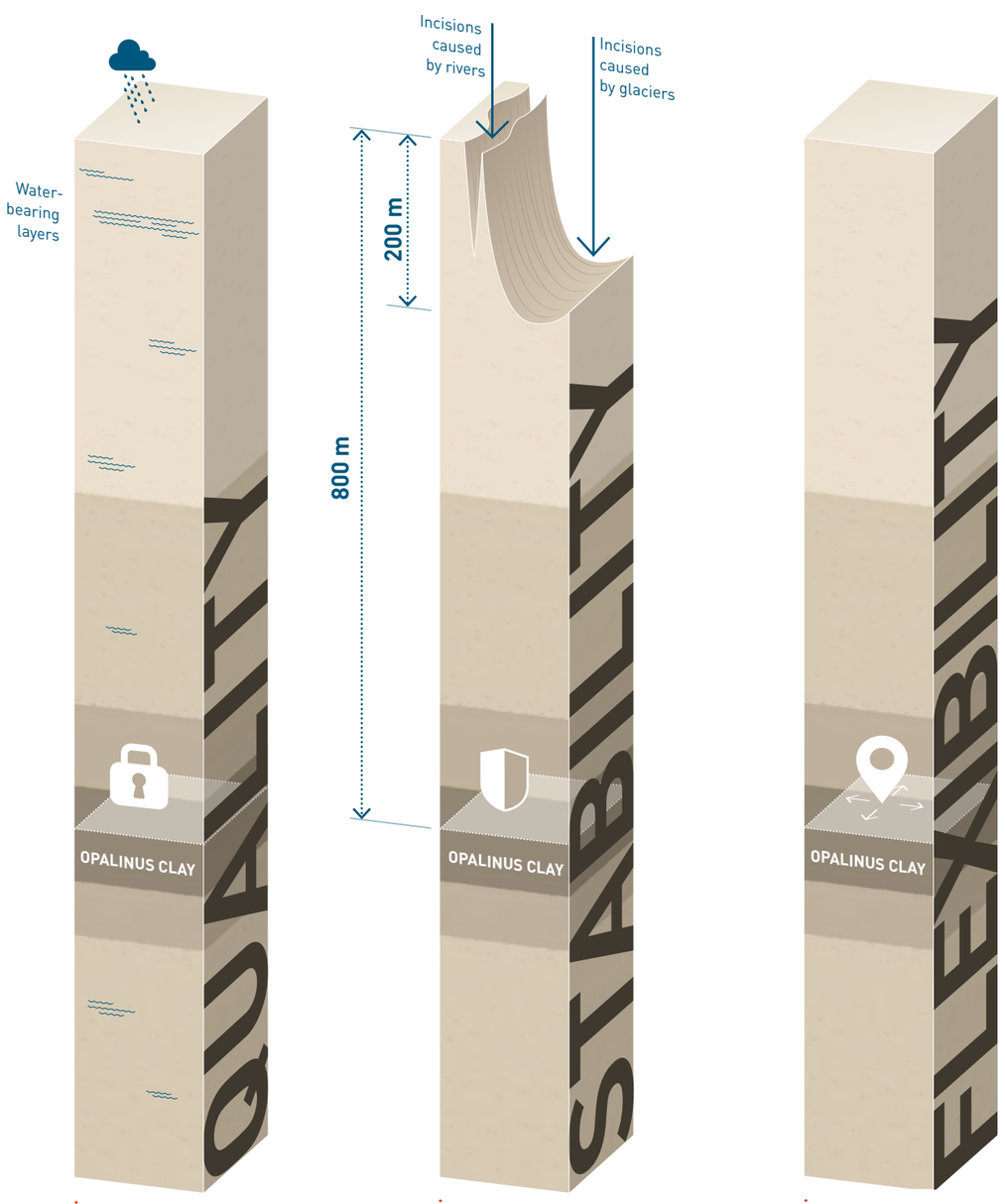
Stability of the geological barrier: The Opalinus Clay has to safely enclose the waste not only today, but also in the distant future. Natural influences such as erosion by glaciers and rivers can change the landscape at the surface and below ground. The host rock in Nördlich Lägern provides the best protection of the repository from such processes, partly due to its greater depth. As a result, it also ensures the greatest long-term stability.

Flexibility: As the underground rock formations in Nördlich Lägern have the largest connected area without major geological faults, they provide maximum flexibility for the construction of the repository. From Nagra's point of view, the Nördlich Lägern siting region has the best overall safety reserves and is therefore the most suitable region for a deep geological repository.

However, a repository is not only made up of underground facilities. Infrastructure is also needed at the surface for the construction and operation of the repository. Parallel to clarifying underground conditions, Nagra also worked together with the affected regions and cantons to determine where to place the surface infrastructure.

In the case of the Nördlich Lägern siting region, the Haberstal area in the community of Stadel was identified. Following a comparison with other areas, the region and Canton Zürich voted in favour of this site for the surface facility. From there, the underground section of the repository will be constructed, operated and monitored. A transloading facility for excavation and construction materials located in the Hardrüttenen section of the community of Weiach will connect the facility to the existing railway network.

The encapsulation plants – where the waste will be packaged for disposal – will be constructed at the Zwilag interim storage facility in the community of Würenlingen. Zwilag's existing infrastructure provides the greatest synergies, for example for the encapsulation plant for high-level waste. This plant will also require less space at the interim storage facility than it would at the surface facility in Stadel. In addition, less forest will have to be cleared and less soil removed. The plant can easily be integrated in the existing industrial complex of the interim storage facility.

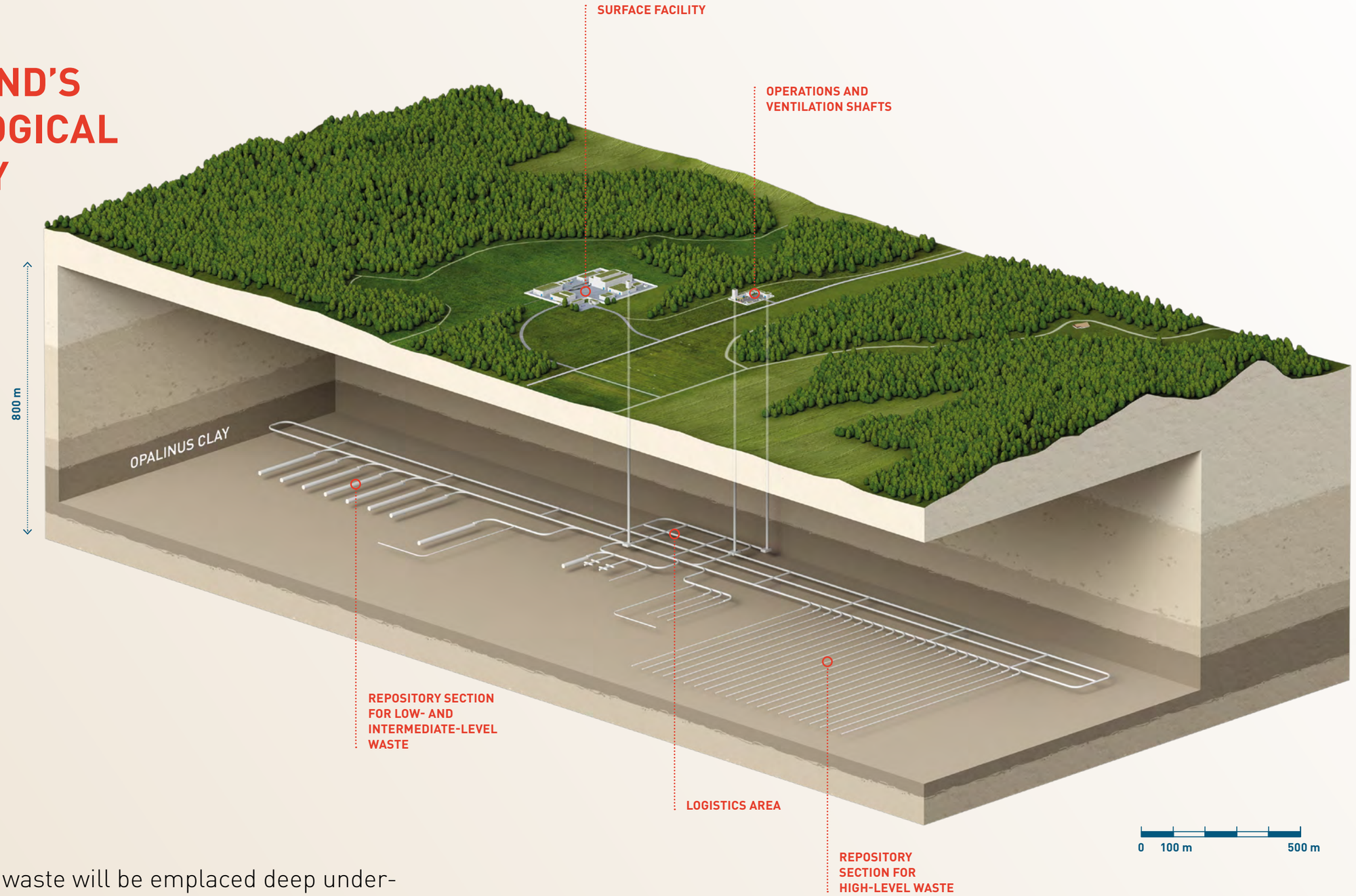


THE GEOLOGICAL BARRIER IN NÖRDLICH LÄGERN HAS THE BEST WASTE CONTAINMENT CAPACITY.

IN NÖRDLICH LÄGERN, THE LONG-TERM STABILITY OF THE GEOLOGICAL BARRIER IS GREATEST.

NÖRDLICH LÄGERN HAS THE LARGEST SUITABLE AREA, THUS PROVIDING THE GREATEST FLEXIBILITY FOR THE LAYOUT OF THE REPOSITORY.

SWITZERLAND'S DEEP GEOLOGICAL REPOSITORY



The radioactive waste will be emplaced deep underground in a tight rock formation. Surface facilities will be required for construction and operation. Shafts will connect these surface facilities to the underground repository.

FURTHER INFORMATION

- Deep geological repositories / Swiss Federal Office of Energy
- Deep geological repositories / Swiss Federal Nuclear Safety Inspectorate
- Combined repository
- Standortunabhängiger Vergleich eines Kombilagers mit zwei Einzellagern hinsichtlich Bau- und Betriebsabläufen sowie Umwelt (Nagra Work Report NAB 19-15, in German)

THE TASK

"We already have radioactive waste, and it is our responsibility to dispose of it safely and for all time – so that future generations will not have to concern themselves with it."

PHILIPP SENN, DIVISION HEAD COMMUNICATION AND PUBLIC AFFAIRS

A trained engineering geologist, Philipp Senn joined Nagra to mediate between science and society.

Nagra has been conducting research to develop a safe solution for 50 years – such as here, at the Grimsel Test Site.

SAFETY FOR FUTURE GENERATIONS

Switzerland's radioactive waste is to be disposed of in a deep geological repository – where it will no longer pose a hazard.

Eighty percent of Switzerland's radioactive waste is produced by the nuclear power plants and 20 percent from applications in medicine, industry and research. Based on the assumption of a 60-year operating lifetime of the nuclear power plants, by 2070, a total of around 82,000 cubic metres of waste will have arisen, including packaging. This is roughly equivalent to two thirds of the volume of the historic part of the Zürich train station terminal.

TWO WASTE CATEGORIES

Waste is divided into high-level waste and low- and intermediate-level waste. Around 10 percent of the waste is highly active and mainly consists of spent fuel assemblies and vitrified waste from reprocessing. The remaining 90 percent is low- and intermediate-level waste, mainly arising from the operation and dismantling of the nuclear power plants and, to a smaller extent, from different applications in medicine, industry and research.

These radioactive substances must be safely isolated until their radioactivity has decayed to a level at which they are no longer hazardous. At the beginning, this process occurs more quickly: after 1,000 years, only a little more than 1.5 percent of the radioactivity remains. Over time, radioactivity decreases more slowly. After 200,000 years, high-level waste will have decayed to the radiotoxicity level of the originally mined uranium ore. Low- and intermediate-level waste does not radiate as long: after approximately 30,000 years, it will be as radioactive as natural granitic rock.

FURTHER INFORMATION

- Types of radioactive waste / Nagra
- Disposal of waste from medicine, industry and research / Swiss Federal Office of Public Health (in German and French)
- How long does radioactive waste emit radiation? (in German and French)

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Nagra has been conducting experiments at the Mont Terri Rock Laboratory for over 25 years.

WHY SWITZERLAND NEEDS A DEEP GEOLOGICAL REPOSITORY

For decades, national and international experts have searched for a solution to safely contain radioactive waste over a period of hundreds of thousands of years. Deep below the surface, time practically comes to a standstill, which is why there is now broad consensus that deep geological disposal is the best solution. Switzerland has anchored the requirement for a repository in its legislation.

Today, there is broad, international scientific agreement that high-level waste should not be stored at the surface in the long term. Deep geological repositories are considered to be the best solution as they enclose the radioactive waste in suitable rock formations located several hundreds of metres below the surface. Repositories are either being planned or already under construction in several countries around the world. Switzerland has also decided in favour of a deep geological repository and has anchored this in the Nuclear Energy Act. As opposed to other countries, Switzerland will also dispose of low- and intermediate-level waste in a deep geological repository rather than at the surface. To ensure that radioactive waste cannot harm humans and the environment, Switzerland has specified that a period of up to one million years must be considered when planning the repository.

DISPOSAL WHERE TIME IS NOT AN ISSUE

No one can predict how society will evolve in the future. This does not apply to conditions below ground. Here, time is virtually at a standstill, in many places for millions of years. For this reason, scientists can make reliable predictions regarding underground conditions – even far into the future. From a geological point of view, a containment period of up to one million years is a manageable time frame. Once the repository has been closed, it will provide passive safety – in other words, it will be safe without the need for human intervention. The repository will be monitored at least until its final closure around one hundred years from now. Until then, it will remain possible to retrieve the waste back to the surface without undue effort should this prove necessary.

FURTHER INFORMATION

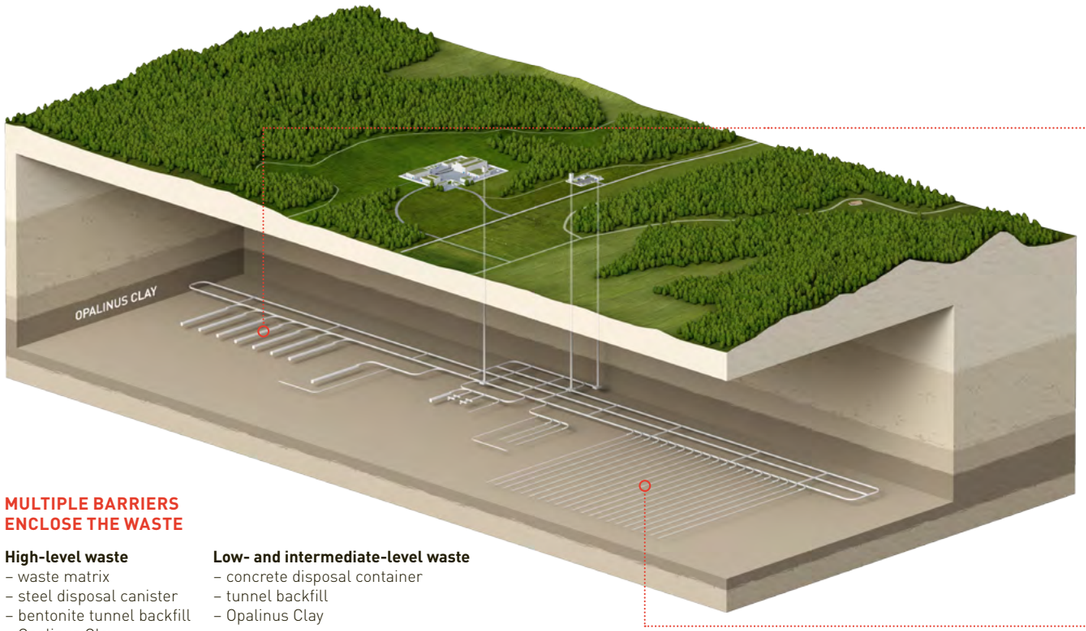
- Swiss Nuclear Energy Act
- Final report of the Swiss Expert Group on Disposal Concepts for Radioactive Waste

THE SOLUTION: A DEEP GEOLOGICAL REPOSITORY

"Our solution is based on an optimum interplay of science and technology – and on a rock that can contain the radioactive waste for a very long time."

SEVERIN WÄLCHLI, DIVISION HEAD PLANNING & CONSTRUCTION

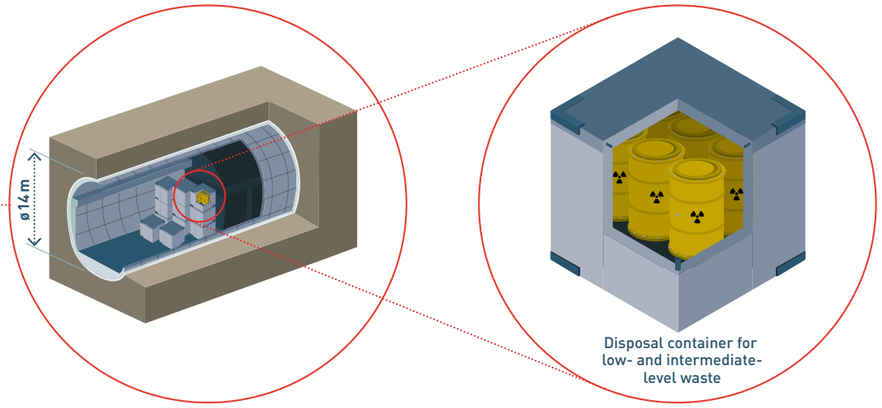
Since studying mechanical engineering and obtaining a doctorate in process engineering at the Swiss Federal Institute of Technology Zürich, Severin Wälchli has worked in the specialist field of safety of underground structures for many years. Today, he is in charge of planning and eventually constructing a repository for Nagra.

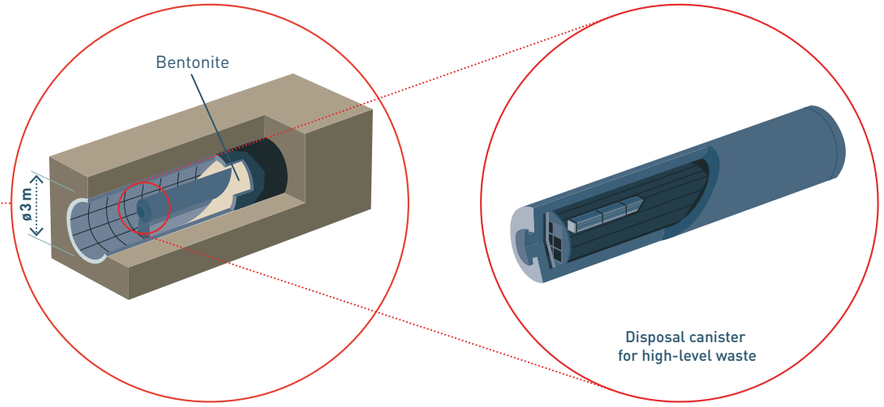


MULTIPLE BARRIERS ENCLOSE THE WASTE

High-level waste
– waste matrix
– steel disposal canister
– bentonite tunnel backfill
– Opalinus Clay

Low- and intermediate-level waste
– concrete disposal container
– tunnel backfill
– Opalinus Clay





HOW THE SWISS REPOSITORY WORKS

The deep geological repository prevents radioactive substances from the waste from reaching the surface and thus our human habitat. This is achieved with the help of a multi-barrier system consisting of several independent, successive safety barriers. The most important geological barrier is the Opalinus Clay rock.

Northern Switzerland has a layer of Opalinus Clay that is located at a depth of several hundred metres and is over one hundred metres thick. The Opalinus Clay has properties that are key for the long-term containment of radioactive waste: it is mostly water-impermeable, self-seals fissures and binds radioactive substances.

ENGINEERED AND GEOLOGICAL BARRIERS

Several independent, successive safety barriers ensure that the radioactive waste will remain in the repository even in the case of highly unlikely events.

The highly radioactive substances in spent fuel assemblies are enclosed in uranium oxide fuel pellets; those from reprocessing are embedded in a glass matrix. This waste matrix has a very low solubility and forms the first of the engineered barriers. The second barrier is the thick-walled, steel disposal canister that encloses the radioactive waste. The tunnel backfill forms the third barrier. Once the disposal canisters have been emplaced, the drifts are backfilled with granular bentonite material. Bentonite has properties similar to those of the Opalinus Clay: it can bind radioactive substances and contain them. The fourth barrier – and most important for long-term safety – is formed by the Opalinus Clay and additional clay-rich rock formations located above and below the Opalinus Clay, so-called confining geological units.

Low- and intermediate-level waste is also enclosed within multiple safety barriers. The solidified waste is packaged into drums, which are then placed in large, concrete disposal containers. The concrete containers are stacked in caverns in the Opalinus Clay. Any cavities are backfilled, and the caverns are then sealed and closed. Again, the Opalinus Clay forms the most important geological barrier.

FURTHER INFORMATION

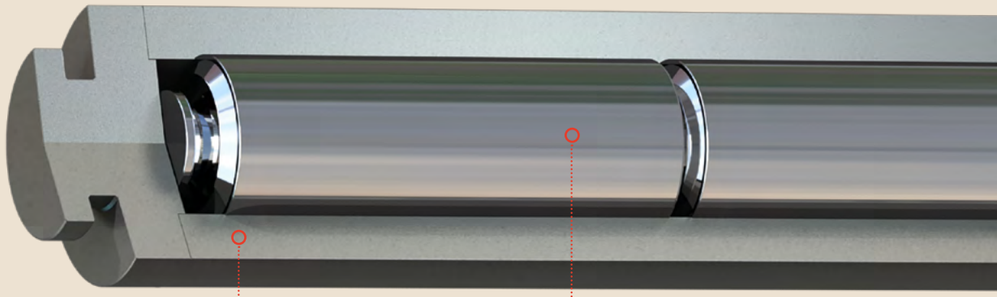
– Brochure: Radioactive Waste Disposal – Why Choose a Deep Geological Repository? (in German)
– Deep Geological Repositories – Safe Disposal of Radioactive Waste / Swiss Federal Nuclear Safety Inspectorate (in German)
– Scientific and Technical Basis for the Geological Disposal of Radioactive Wastes / International Atomic Energy Agency

THE DISPOSAL CANISTER: EXAMPLE OF AN ENGINEERED BARRIER

The thick-walled canister is an important barrier for high-level waste. This canister can isolate the spent fuel assemblies for at least 10,000 years. During this time, the level of radioactivity will decrease significantly.

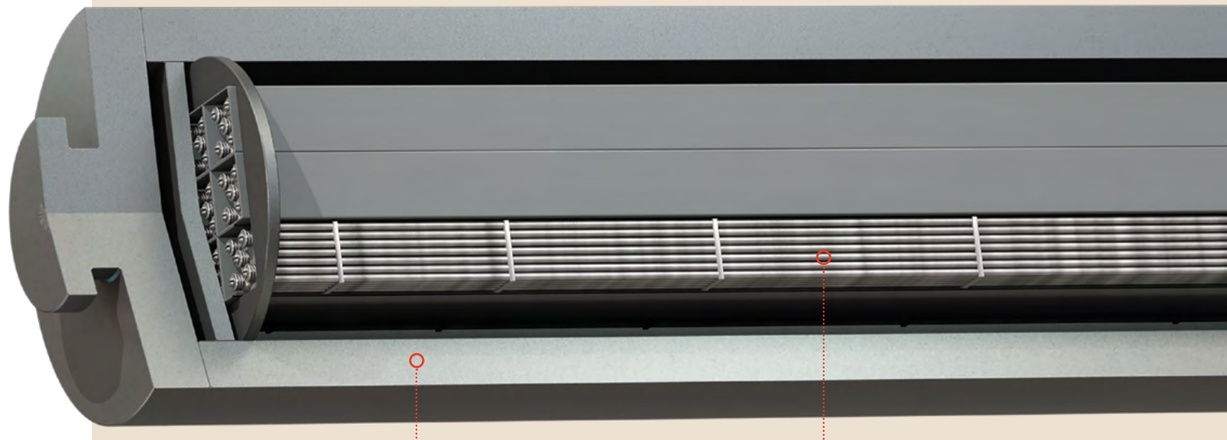
The thick-walled, steel disposal canisters contain high-level waste from the nuclear power plants in the form of spent fuel assemblies or vitrified waste from reprocessing. The authorities call for the disposal canisters to remain tight for at least 1,000 years. Results of experiments conducted at the Mont Terri Rock Laboratory and model calculations show that disposal canisters corrode very slowly and can be expected to remain tight for at least 10,000 years. Over the course of millennia, the radioactivity of the spent fuel assemblies will continuously decrease: after 10,000 years, it will amount to only 0.5 percent of the original level. When the canisters develop leaks, the subsequent barriers will keep the radioactive substances away from the human habitat.

Even though the present-day disposal canister remains tight ten times longer than legally required, Nagra's scientists are researching how to further increase the canister's longevity – for example, by using a copper coating. The definitive design does not have to be decided for around another twenty years. Until then, all new scientific and technological insights will feed into the development of an optimised disposal canister.



DISPOSAL CANISTER FOR FLASKS CONTAINING VITRIFIED HIGH-LEVEL WASTE

FLASK CONTAINING VITRIFIED WASTE
The flasks contain vitrified waste from reprocessing.

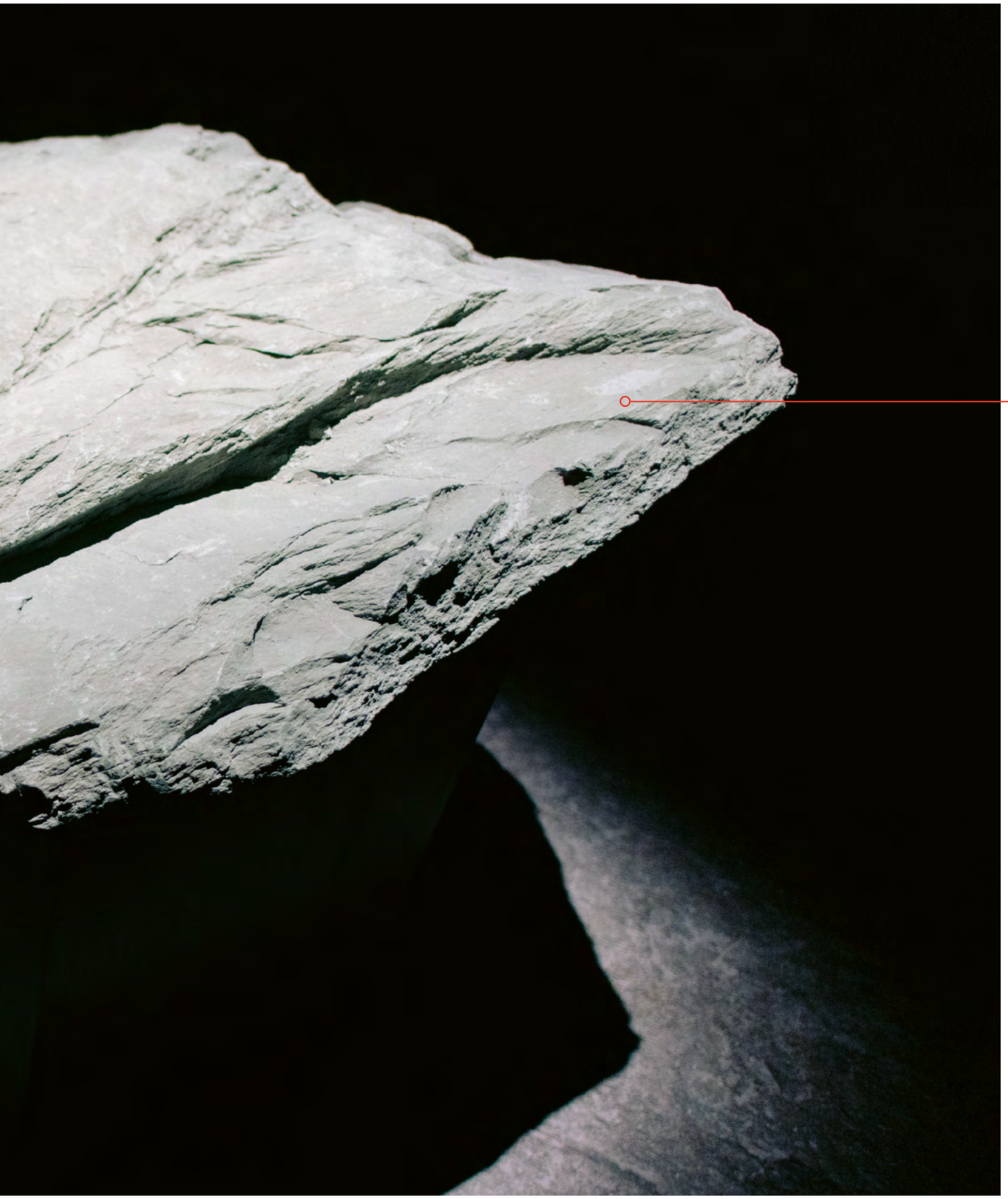


DISPOSAL CANISTER FOR SPENT FUEL ASSEMBLIES

SPENT FUEL ASSEMBLIES
Most of the high-level waste consists of spent fuel assemblies.

FURTHER INFORMATION

- Container Material for Radioactive Waste / Swiss Federal Nuclear Safety Inspectorate (in German)
- Development of Copper-Coated Canisters for the Disposal of SF and HLW in Switzerland (Nagra Technical Report NTB 20-01)
- Canister Design Concepts for Disposal of Spent Fuel and High-Level Waste (Nagra Technical Report NTB 12-06)



THE OPALINUS CLAY: THE MOST IMPORTANT GEOLOGICAL BARRIER

The Opalinus Clay is largely impermeable to water, can self-seal fissures and has the capacity to bind radioactive substances. For these reasons, this clay rock is the most important geological barrier of the deep geological repository.

For the first 10,000 years or longer, the disposal canister will retain the radioactive substances from the spent fuel assemblies. When the canister eventually develops a leak, the bentonite tunnel backfill will retain most of the substances until they are no longer radioactive. The Opalinus Clay does not have to assume its barrier role for several tens of thousands of years. By this time, most of the radioactivity will have decayed.

THE PROPERTIES OF THE OPALINUS CLAY

Three decisive properties are responsible for making the Opalinus Clay the most important geological barrier of the deep geological repository. First, it is largely impermeable to water. This means that deep, flowing groundwater in the rock formations above and below the Opalinus Clay cannot come into contact with the radioactive waste.

Second, should fissures form in the Opalinus Clay during repository construction or over the course of hundreds of thousands of years as a result of movements in the rock, the Opalinus Clay can seal these itself. When the Opalinus Clay comes into contact with water, it swells, thereby sealing any fissures. This could be scientifically demonstrated in laboratory experiments, at the Mont Terri Rock Laboratory and in the Rheinau-1 deep borehole.

Third, the Opalinus Clay can bind radioactive substances over the long term as the rock partly consists of clay minerals which belong to the family of sheet silicates. These are made up of small platelets with a negative electrical charge, and the clay minerals thus attract positively charged particles. Most radioactive substances in the waste are positively charged and therefore effectively stick to the Opalinus Clay.

WHAT EXACTLY IS THE OPALINUS CLAY?

The Opalinus Clay formed during the Jurassic Period some 175 million years ago. At that time, Northern Switzerland was covered by a wide, shallow sea. Fine clay muds were deposited on the seabed where they solidified to form the Opalinus Clay. Its name is derived from the ammonite “Leioceras opalinum” found in it.

FURTHER INFORMATION

– Brochure: Clay Rocks and Their Contribution to Radioactive Waste Disposal

THE SEARCH FOR A SITE

"Geology is the decisive factor: we have based our search for the safest site on this principle. Rocks with a 'dull' past offer the best conditions for a safe deep geological repository."

TIM VIETOR, DIVISION HEAD SAFETY AND GEOLOGY

As a geologist, Tim Vietor worked for various research institutes, which included stays in Africa and South America. His focus: tectonics and geophysics. He has been working for Nagra since 2005.

SITE SELECTION PROCESS

The search for the safest repository site is being carried out in line with the "Sectoral Plan for Deep Geological Repositories". The Federal Government has the lead in this broadly-based procedure. The safety of humans and the environment has the highest priority.

After several years of preparation, the site selection process for a deep geological repository was started in 2008 under the lead of the Swiss Federal Office of Energy.

The underground geological conditions are decisive for the successful long-term containment of the radioactive waste. For this reason, the Swiss repository will be constructed at the site with the best geological conditions nation-wide. These are evaluated using pre-defined safety criteria that are at the core of the site selection process: the safety of humans and the environment has the highest priority.

The safety of the surface facilities during the operational phase mainly relies on their design and less on the selected site. This is why discussions with the affected regions and cantons regarding the question of where to place what types of facilities at the surface can also include spatial-planning aspects and site-relevant concerns.

WHO IS RESPONSIBLE FOR WHAT?

The Swiss Federal Office of Energy leads the Sectoral Plan process on behalf of the Federal Council and, within the framework of regional participation, involves the potential siting regions in the process. This means that communities, cantons, the public and interested organisations from the potential siting regions as well as from neighbouring Germany accompany the site selection process and can raise their concerns. The regional conferences lie at the core of regional participation: they represent the interests of the regions and can, for example, state their position on the surface infrastructure of the repository in connection with Nagra's siting proposals.

The cantons support the Federal Government in the site selection process and the communities in becoming actively involved.

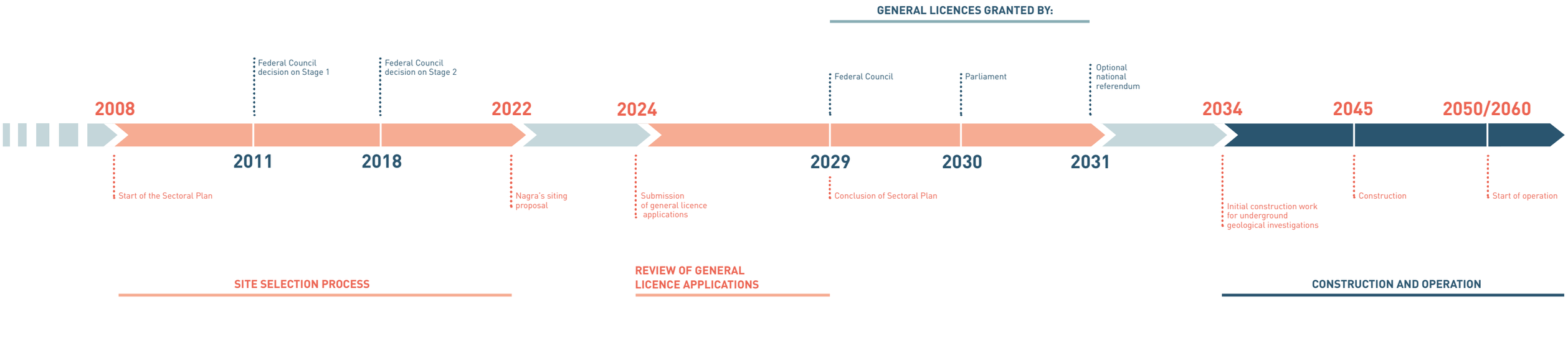
Nagra's mandate is to plan and construct the deep geological repository. After decades of research, it has created a solid scientific foundation. Based on this, it is now in a position to propose the most suitable site for a deep geological repository and expects to submit the general licence applications to the Federal Government in 2024.

The Swiss Federal Nuclear Safety Inspectorate supports the process in its role as regulatory authority and formulates safety requirements. It also reviews and evaluates Nagra's work, in particular the general licence applications.

Current planning foresees that the Federal Council will decide in 2029 on Nagra's general licence applications and present its decision to the Federal Parliament for approval. The decision of Parliament is subject to an optional national referendum. If the referendum is called for, Swiss voters will have the final say – around 2031.

FURTHER INFORMATION

- Deep Geological Repositories Sectoral Plan / Swiss Federal Office of Energy
- Sectoral Plan process / Canton Zürich (in German)
- Sectoral Plan process / Canton Aargau (in German)
- Waste Management / Swiss Federal Nuclear Safety Inspectorate



STEP BY STEP TO THE SAFEST SITE

Nagra investigated the whole of Switzerland in its search for suitable sites for a deep geological repository. The potential siting regions were narrowed down step by step in a three-stage process.

The goal of the site selection process is to identify the safest site for a repository in Switzerland – in collaboration with a multitude of actors. This procedure is divided into three stages. Each stage concludes with a decision of the Federal Council.

Stage 1: "Blank " map of Switzerland
In Stage 1 of the site selection process, regions were identified that, based on defined criteria, were potentially suitable sites for deep geological repositories. The starting point was a "blank" map of Switzerland. Nagra looked at suitable regions and rock formations all over Switzerland and identified six potential siting regions. At the end of Stage 1, the Federal Council gave Nagra the mandate to further investigate these six regions.

Stage 2: Narrowing down the regions
All six potential siting regions were compared with each other in line with stipulations of the federal authorities. This stage also included defining siting areas for the surface facility of a repository in collaboration with the siting regions. At the end of Stage 2, the Federal Council designated Jura Ost, Nördlich Lägern and Zürich Nordost as the remaining siting regions, along with corresponding areas for the surface facility – and also specified the Opalinus Clay as the host rock for the repository.

Stage 3: In-depth investigations
The three remaining siting regions were investigated in detail in Stage 3. As a result, Nagra is now in the position to propose a repository site.

CRITERIA IN THE SITE SELECTION PROCESS

The authorities defined four criteria groups with a total of 13 criteria. Nagra has to consider these when selecting the most suitable repository site. Safety has the top priority. Further aspects, such as socio-economic factors, may only play a role if there are no geological differences between the siting regions.

Criteria group 1 – Properties of the host rock and the so-called containment-providing rock zone: the host rock as well as the over- and underlying formations will isolate the radioactive waste. Investigations include measuring the tightness and thickness of the rock, its composition and whether or not the rock formations include any geological fault zones.

Criteria group 2 – Long-term stability: investigations focus on determining whether the properties of the rock and the site remain stable. Erosion by glaciers and rivers could impair the protective function. The repository can also negatively impact the rock, for example, through heat generated by the waste or through gas produced as a result of corrosion processes.

Criteria group 2 also considers potential conflicts of resources: should a region possess considerable occurrences of natural resources such as oil or gas, future generations could be motivated to recover these resources – and thus threaten the containment of the waste.

Criteria group 3 – Reliability of geological findings: the focus is on evaluating how well the regions can be investigated and data can be collected and on how accurately these data can help to predict the long-term evolution.

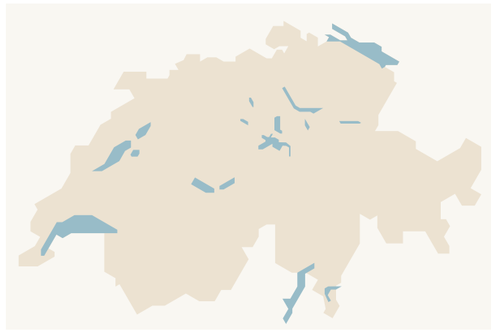
Criteria group 4 – Engineering suitability: these criteria are used to evaluate how well suited the underground is for the construction of a deep geological repository.

A comparison of the sites thus considers the quality of the geological barrier, its long-term stability and the predictability and engineering suitability of the underground.

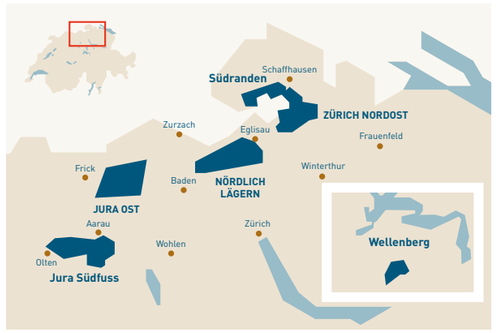
FURTHER INFORMATION

- Deep Geological Repositories Sectoral Plan Stage 1 / Swiss Federal Office of Energy
- Deep Geological Repositories Sectoral Plan Stage 2 / Swiss Federal Office of Energy
- Results report Stage 2 / Swiss Federal Office of Energy (in German)
- Site selection criteria / Swiss Federal Nuclear Safety Inspectorate (in German)

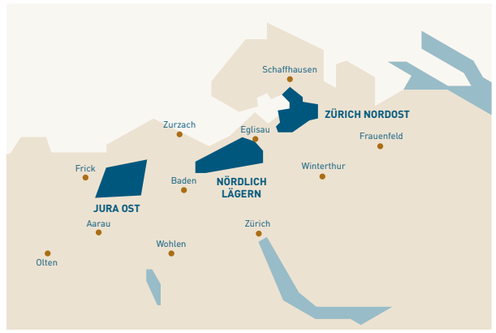
START OF THE SECTORAL PLAN



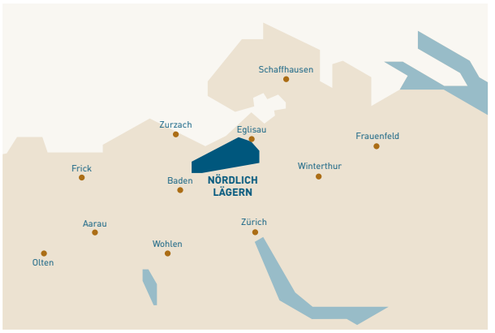
RESULTS OF STAGE 1



RESULTS OF STAGE 2



NAGRA'S SITING PROPOSAL



Start of the Sectoral Plan **2008**

Federal Council decision on Stage 1 **2011**

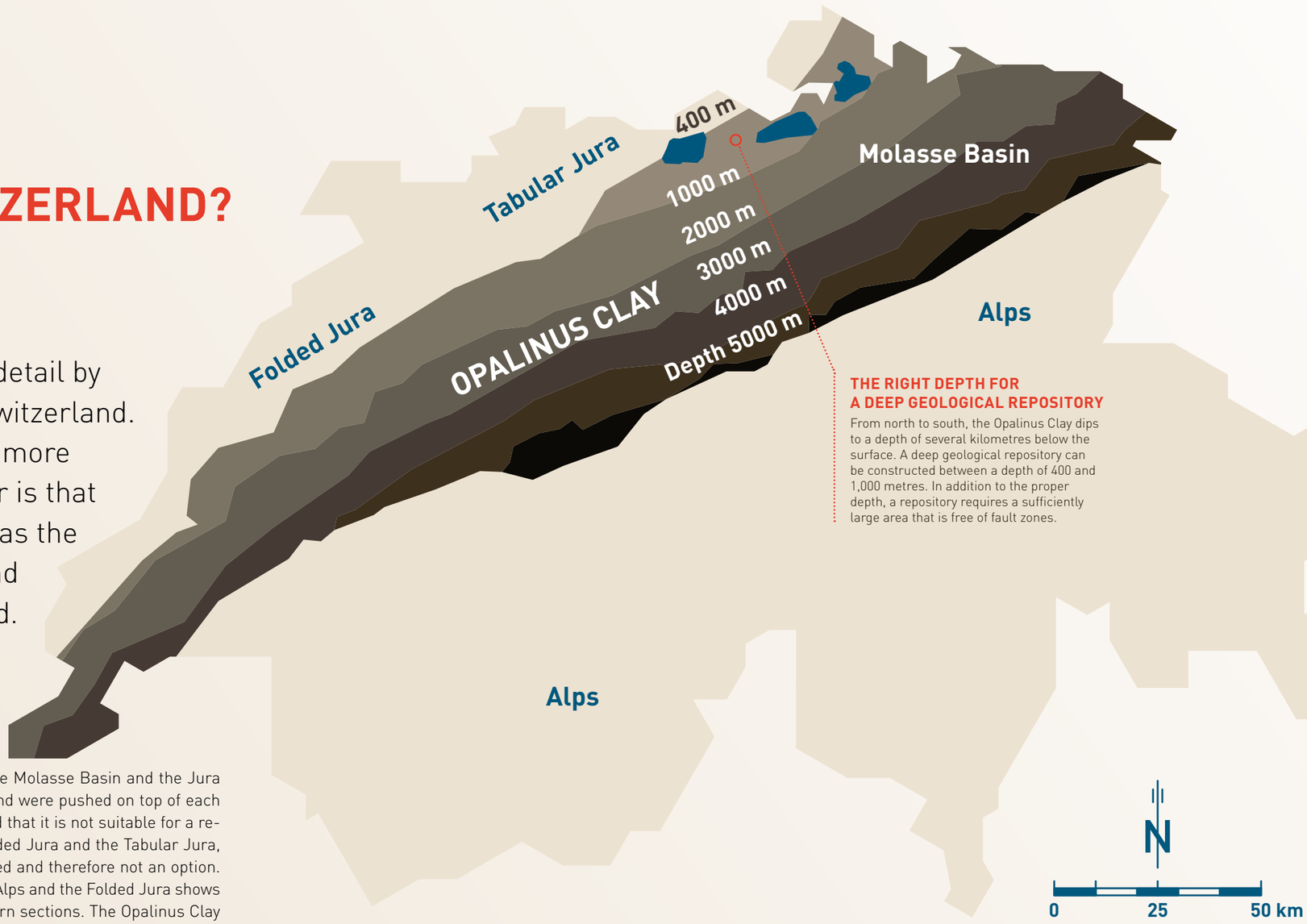
Federal Council decision on Stage 2 **2018**

Nagra's siting proposal **2022**

Submission of general licence applications **2024**

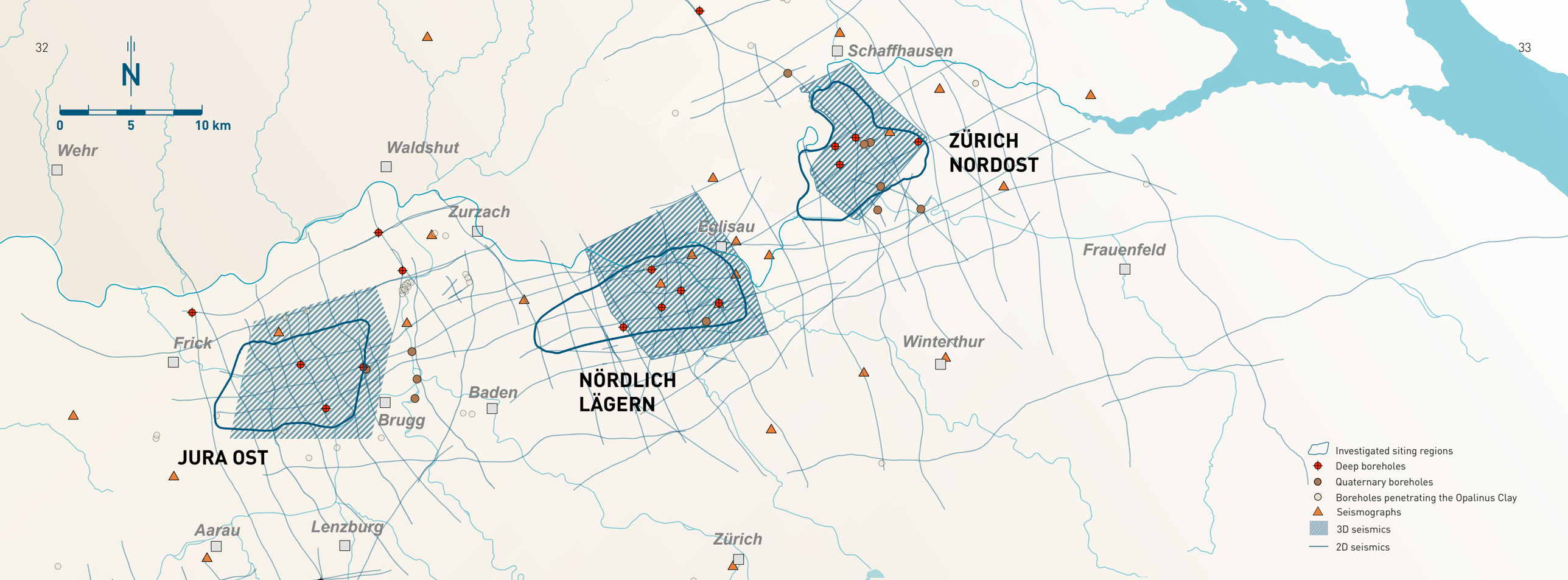
WHY NORTHERN SWITZERLAND?

All three regions investigated in detail by Nagra are located in Northern Switzerland. Why is this corner of the country more suitable than others? The answer is that this is where the Opalinus Clay has the ideal depth, quality and extent and is also comparatively undisturbed.



Switzerland can be roughly divided into three regions: the Alps, the Molasse Basin and the Jura Mountains. During the alpine orogeny, rock formations fractured and were pushed on top of each other. The underground in the alpine region is so strongly deformed that it is not suitable for a repository – or at least not for a high-level waste repository. The Folded Jura and the Tabular Jura, both located in northwest Switzerland, are mostly strongly deformed and therefore not an option. In contrast, the Molasse Basin (Swiss Plateau) located between the Alps and the Folded Jura shows considerably less deformation, particularly in the central and eastern sections. The Opalinus Clay is also found here. In the Folded Jura and in the very north of Switzerland, it is located close to the surface. From there, it continuously dips towards the Alps where it reaches a depth of several kilometres.

The construction of a deep geological repository requires comparatively large areas that show little deformation. At the same time, the Opalinus Clay also has to be located at the right depth: between 400 and 1,000 metres. These two conditions are met only in the Molasse Basin of Northern Switzerland, both at its northern margin and in the adjacent, eastern part of the Tabular Jura. This is also where the three siting regions are situated, which Nagra has investigated in detail over the past few years.



DATA BASIS FOR DECISION-MAKING

In recent years, the Jura Ost, Nördlich Lägern and Zürich Nordost siting regions have been comprehensively investigated. The data basis is now so extensive and the picture of the underground so complete that Nagra can determine the safest site for a repository.

FURTHER INFORMATION

- In detail: Data accumulation over time
- Brochure: Deep Boreholes

In Stage 3 of the site selection process, Nagra conducted in-depth investigations of all three potential siting regions. The investigation programme cost around CHF 250 million. Since 2019, Nagra has drilled nine deep boreholes. On average, these reached a depth of around 1,000 metres and penetrated more than 10,000 metres of rock. A total of 6,000 metres of drill cores were brought to the surface. Over 4,000 samples were analysed in laboratories in Switzerland and abroad, e.g. in Japan and Australia. The purpose of these analyses was to look at the strength and tightness of the rock. Tests were carried out in all the boreholes, for example, measurements of the rock stress.

OBTAINING AN IMAGE OF THE UNDERGROUND

Aside from the deep boreholes, 11 shallower boreholes were drilled, so-called Quaternary boreholes. As a result of these Quaternary boreholes, Nagra now has a better understanding of how rivers and glaciers shaped landscape features in the past. This understanding of past processes allows Nagra to make statements on the future evolution of the landscape.

Boreholes provide only a selective image of the subsurface. For this reason, extensive seismic measurements were also conducted. This involved generating acoustic waves at the surface, and measuring the echo reflected back by the boundaries of rock formations. With this method, a three-dimensional image of the underground could be obtained – roughly comparable to creating an ultrasound image. A total of around 250 square kilometres were measured using seismics.

This combination of seismic measurements and information on rock properties obtained from the deep borehole campaign provides a comprehensive understanding of the geology in the three siting regions.

Further insights were gained from experiments conducted at the Mont Terri Rock Laboratory and investigations of rocks at the earth's surface. Data from thousands of shallow boreholes, often drilled for geothermal probes, were also included. Nagra's siting proposal is based on this comprehensive data basis. Some investigation results have already been published, and the remaining data are published on an ongoing basis on Nagra's website and in scientific publications. In the general licence applications that Nagra expects to submit in 2024, the data basis will be compiled in detail.

COMMONALITIES AND DIFFERENCES

Nagra has conducted in-depth investigations to identify commonalities and differences in the three siting regions.

The distance from Jura Ost via Nördlich Lägern to Zürich Nordost is around 50 kilometres and thus relatively small. The geological history is similar in all three siting regions, and it is therefore not surprising that the geological conditions in the regions bear strong resemblances and that a safe deep geological repository could be constructed in any of these regions.

In all three siting regions, the Opalinus Clay can be found with the required thickness, quality and depth. This means that all three regions score well in criteria group 1 (properties of the host rock and the containment-providing rock zone).

The regions also share an important commonality for criteria group 2 (long-term stability): in geological terms, all three siting regions are very stable over a long time period. In all three regions, the repository is protected from erosion caused by glaciers and rivers. In addition, so-called repository-induced effects, such as the generation of heat or gas pressure, barely destabilise the rock. None of the three regions has significant natural resources whose exploitation could impact the barrier performance. Resource conflicts therefore do not play an important role.

In criteria group 3 (reliability of geological findings), the commonalities clearly outweigh the differences. The geological evolution can be reliably predicted in all three regions, and the Opalinus Clay is consistently homogeneous.

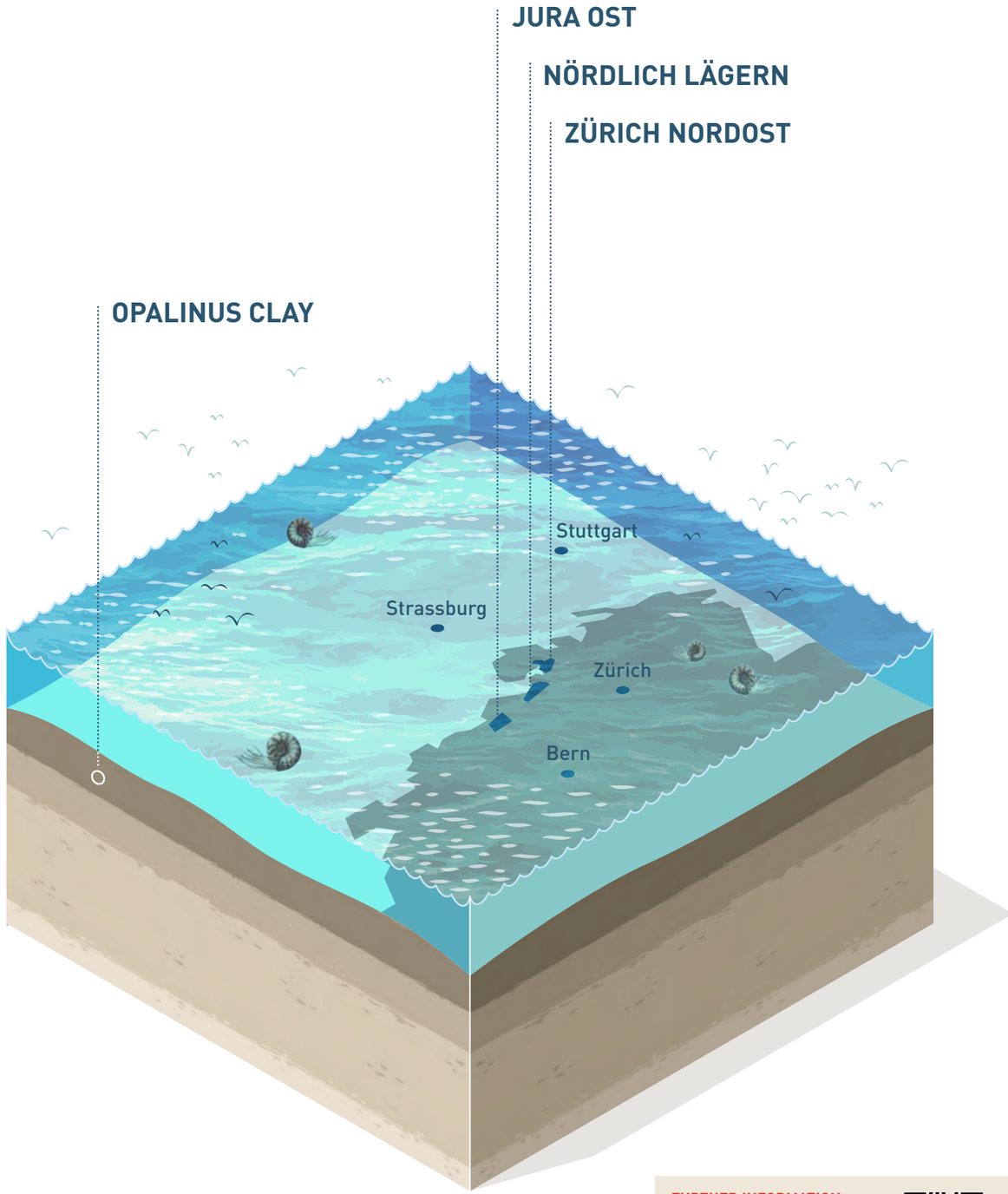
During Stage 3 of the Sectoral Plan process, Nagra gained new data and findings relating to criteria group 4 (engineering suitability). In Stage 2 of the Sectoral Plan, Nagra argued that Nördlich Lägern would be less suitable from an engineering perspective than the other two siting regions.

NAGRA REVISES ITS ASSESSMENT

At the time, the Swiss Federal Nuclear Safety Inspectorate criticised that Nagra's assessment was not sufficiently supported by data. For this reason, Nördlich Lägern had to undergo the same further in-depth investigations as the other two remaining siting regions.

From today's point of view, Nagra's assessment in Stage 2 was too cautious. With the help of the currently available, comprehensive data basis, Nagra was able to reassess the engineering suitability. Thanks to the comprehensive data basis now available, Nagra is convinced that it can safely construct and operate a repository in all three regions.

In addition, Nagra has now decided to proceed with an excavation technique using pre-fabricated concrete elements, or liners, that simplify tunnel construction at greater depth.



DEPOSITION OF THE OPALINUS CLAY
Around 175 million years ago, "Central Europe" looked completely different. In a shallow sea, small debris and sediments from the mainland were deposited very uniformly, forming the layer of Opalinus Clay rock.

FURTHER INFORMATION
- "Stein" (pocket-sized hard-cover book on rocks, available in German)
- Geological evolutionary history of Northern Switzerland

BESIDES COMMONALITIES, THERE ARE ALSO RELEVANT DIFFERENCES

While all regions satisfy the requirements for criteria groups 1 to 3, Nagra has found some relevant differences. From Nagra's point of view, only criteria group 4 (engineering suitability) shows no relevant differences between the regions that could impact the siting decision.

Criteria group 1: The properties of the host rock and the containment-providing rock are good everywhere – but there are some differences. Investigation results demonstrate the quality of the containment properties of the rock. We thus summarise these differences under "Quality".

Criteria group 2: The rock has to safely enclose the waste not only today, but also in the distant future. While all three regions are stable and protected by the host rock in the long term, their safety reserves are not identical everywhere. The main difference is the varying depth of the Opalinus Clay layer. We summarise these differences under "Stability".

Criteria group 3: Reliable prognoses can be made in all three regions – the corresponding data are very robust. And yet – deviations can never be wholly excluded. For this reason, it is advantageous to select the largest possible, quietly bedded area. A larger, undisturbed area offers more flexibility in the layout of the repository. We summarise these differences under "Flexibility".

The commonalities and differences between the three siting regions were mainly explored by means of deep borehole and seismic investigations.

QUALITY OF THE BARRIER

The Opalinus Clay and the adjacent, similarly tight rock formations prevent the radioactive substances from entering water-bearing rock formations that would transport them to the earth's surface.
The quality of this geological barrier is very high in all three regions, but there are some differences.

The Opalinus Clay forms the core of the geological barrier and the containment-providing rock zone and is similar in all three regions. Safety analyses show that the Opalinus Clay alone can enclose the radioactive waste for a sufficiently long time period.

The so-called confining geological units are located above and below the Opalinus Clay and extend to the next over- or underlying water-bearing rock formations. The confining geological units have a more variable structure in the three siting regions than the Opalinus Clay. However, they are also very tight and make an additional contribution to containment of the radioactive substances and thereby also to long-term safety.

The comparison of the regions shows the differences in terms of the distance to the next water-bearing rock formation. This is partly smaller in the Jura Ost siting region than in the other regions. The distance is greatest in Nördlich Lägern.

In Jura Ost and Zürich Nordost, water-bearing rock formations can be found around 60 metres below the Opalinus Clay. In parts of Nördlich Lägern, the distance to the nearest water-bearing rock formation below the Opalinus Clay is significantly larger than in Jura Ost or Zürich Nordost.

ANCIENT POREWATER

The containment capacity of the geological barrier can be derived based on the age of the water contained in the pores of the Opalinus Clay.

The groundwater contained in the water-bearing rock formations impacts the chemical composition of the porewater in the Opalinus Clay through very slow exchange processes. Past transport processes between the groundwater and the Opalinus Clay have left traces in the porewater – a type of chemical footprint. Based on this, it is possible to derive the extent of the exchange between surface water and porewater in the Opalinus Clay. This process depends on several factors: for example, the thickness and tightness of the rock or whether and how strongly water flows in the adjacent water-bearing rock formations, thereby coming into contact with the surface.

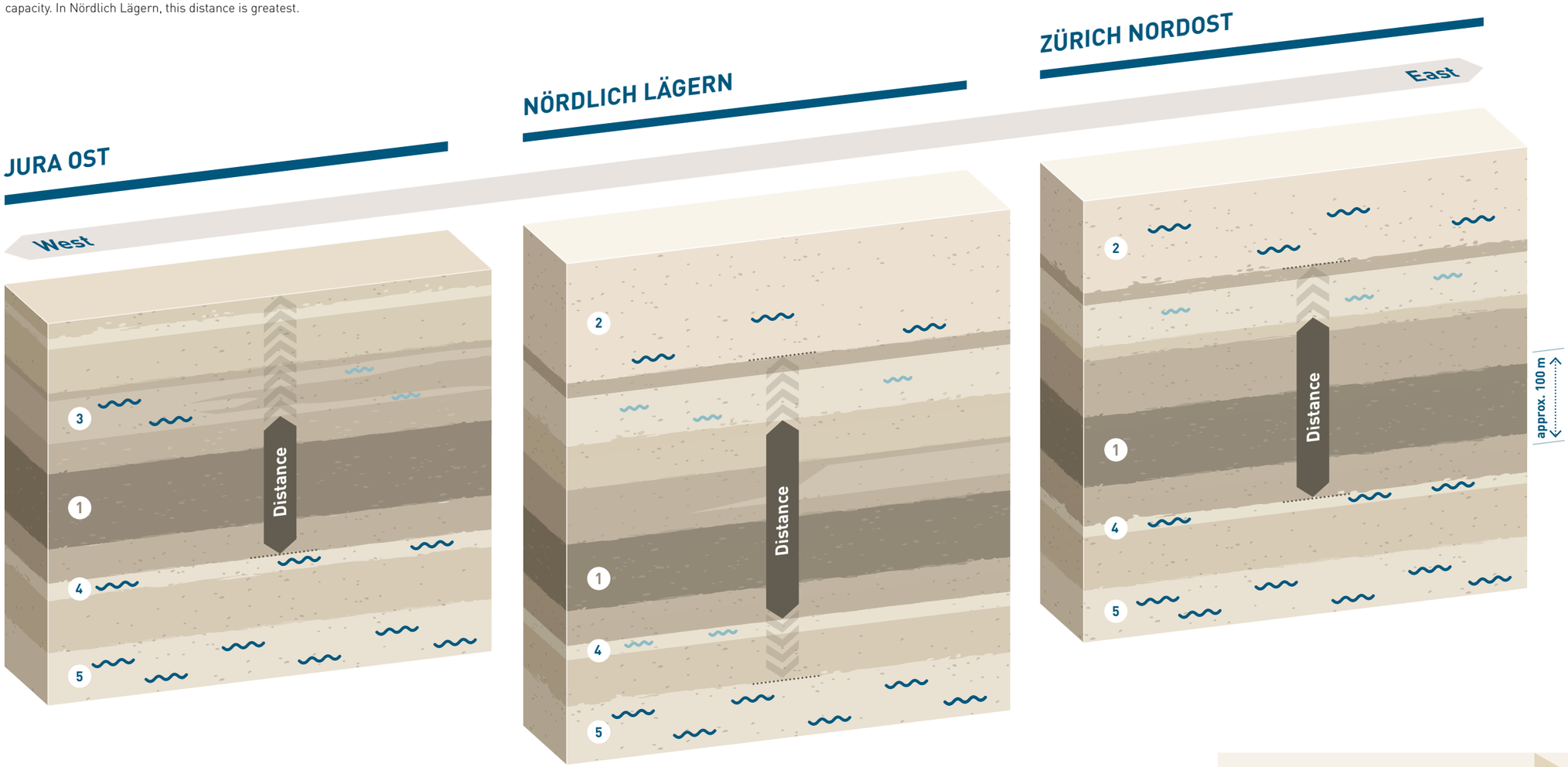
The proportion of "ancient" porewater is highest in Nördlich Lägern. This shows that the barrier function was very effective in the past and that the transport between the Opalinus Clay and the nearest water-bearing rock formations, or the surface water, was very slow. Compared to the other siting regions, the system in Nördlich Lägern is also rated as most favourable with regard to future evolution. In summary, the quality of the barrier is highest in Nördlich Lägern. This is where the rock best encloses radioactive waste.

FURTHER INFORMATION

- In detail: Quality of the geological barrier
- Hydrochemie und Isotopenhydrogeologie von Tiefengrundwässern in der Nordschweiz und im angrenzenden Süddeutschland (Nagra Work Report NAB 13-63, in German)

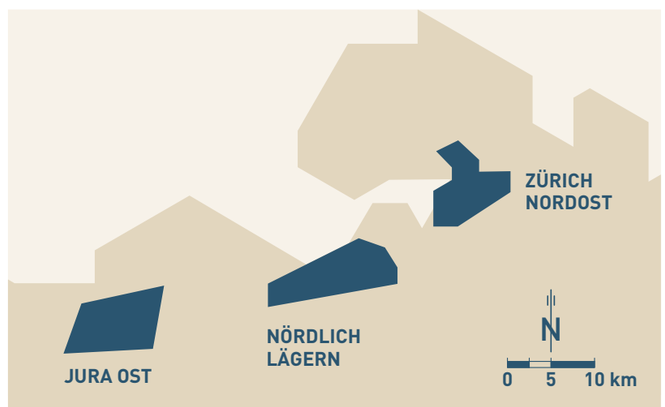
DISTANCES BETWEEN THE OPALINUS CLAY AND THE NEAREST WATER-BEARING ROCK FORMATIONS

Blue symbols indicate water-bearing rock formations. The distance of the Opalinus Clay to these formations impacts the containment capacity. In Nördlich Lägern, this distance is greatest.



1 Opalinus Clay
2 Malm
3 Hauptrogenstein
4 Keuper
5 Muschelkalk

Distance to the nearest water-bearing rock formation
Indications of increased distance to the nearest water-bearing rock formation
Regional groundwater-bearing rock formation
Local groundwater-bearing rock formation



STABILITY OF THE BARRIER

The geological barrier provides long-term stability in all three regions. Underground, the deep geological repository is protected from erosion by glaciers and rivers. However, there are differences regarding the size of the safety reserves.

The long-term stability of the geological barrier is a decisive factor in protecting the repository over very long time periods – in particular from erosion by rivers and glaciers. To ensure that the Opalinus Clay can retain its properties, such as its self-sealing capacity, the rock formations between the repository and the surface must maintain a minimum thickness even hundreds of thousands of years from now. Nagra has to be able to make reliable predictions of future erosion processes. These are based to a considerable extent on an understanding of how the landscape has evolved over the past two million years. Fluvial deposits (gravels) dating back one to two million years can still be found on many hills in Northern Switzerland. At that time, the Rhine and Aare rivers flowed at this elevation. Since then, these rivers have deepened by around 200 to 300 metres.

Glaciers have also left behind clear traces. At the surface, these take the form of moraines and deep troughs such as Lake Zürich. Once the glaciers retreated, many of these troughs were again filled with sediments. Among other factors, the depth of these troughs depends on the extent of the glaciers, the duration of the ice age and on the hardness of the rock incised by the glaciers.

FURTHER INFORMATION

– In detail: Erosion
– Brochure: Erosion

The surface of the earth will change.
The underground will remain stable.

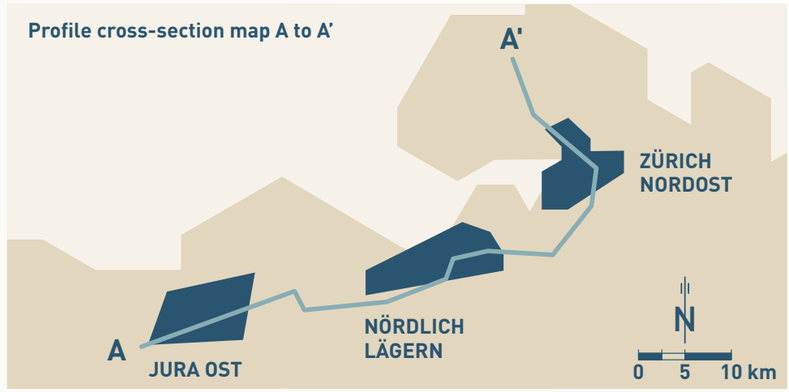
EROSION CAUSED BY RIVERS AND GLACIERS

In all three siting regions, a deep geological repository would be protected from the influences of glaciers and rivers. The geological barrier provides long-term stability in all three regions. However, the safety reserves vary in the three regions.

In Jura Ost, the Opalinus Clay is less deep and more than one third of the rock above the repository is made up by the Bözberg Mountain, which has a higher elevation than the surrounding rivers. Here, the rivers could – albeit in a highly unlikely scenario with a change in the river network – wear down the rock overburden to an extent that the long-term stability of the geological barrier would be reduced.

This risk does not apply to the Zürich Nordost siting region and even less so to Nördlich Lägern. In the past, these two regions were more heavily impacted by glaciation during the ice ages than Jura Ost. Most troughs once formed by glaciers can be found in Zürich Nordost.

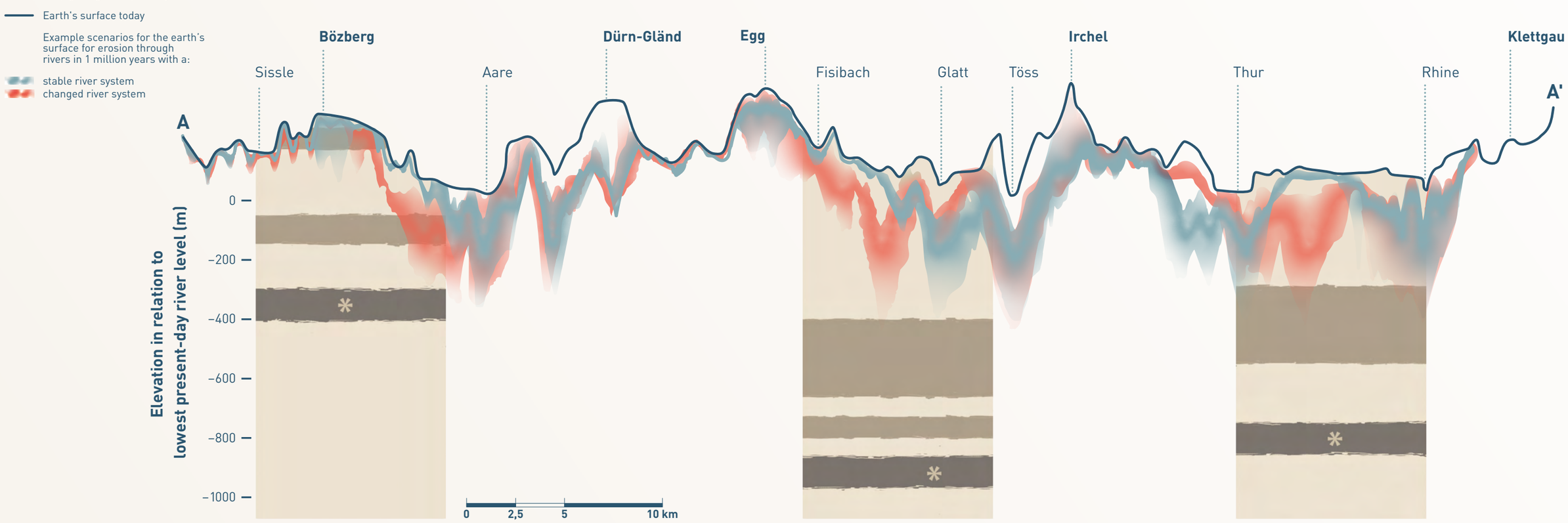
In Nördlich Lägern, the Opalinus Clay is located at a greater depth and is better protected by surrounding hard rock formations than in Zürich Nordost. Nördlich Lägern thus has an additional safety reserve with regard to future erosion and offers the greatest long-term stability.



JURA OST

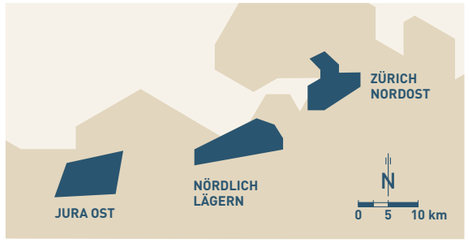
NÖRDLICH LÄGERN

ZÜRICH NORDOST



FLEXIBILITY

Where rock formations move against each other, faults form underground. These are considered to be geological weak points. Large, connected areas without faults are advantageous as they allow more flexibility in designing the repository.



In the geological past, stresses in the earth's crust – for example due to the alpine orogeny – resulted in displacements underground. These can be mapped with the help of seismic measurements. Nagra distinguishes between faults and deformation zones. Faults are fractures in the rock that occur when two or more blocks have visibly shifted relative to each other. Extended areas with large faults are summarised as regional tectonic elements. Deformation zones are slight deformations in the rock without larger mappable fractures.

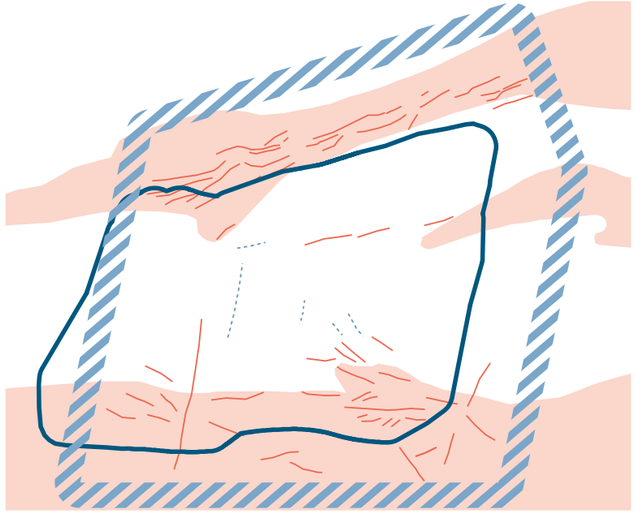
In the past, regional tectonic elements have absorbed most of the displacements as they constitute weak zones. Nagra avoids these in its selection of a site for the repository.

Individual local faults can also be avoided in all three siting regions, but this narrows down the options for the layout of the repository. Due to the self-sealing capacity of the host rock, deformation zones are of little significance with regard to safety. As they are associated with remaining uncertainties, areas without deformations zones are preferred.

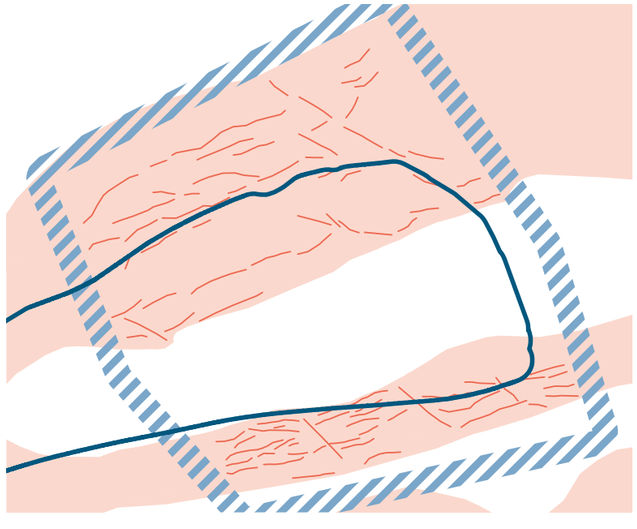
All three siting regions have sufficient space between the faults to allow for the construction of a deep geological repository. In addition, Nördlich Lägern has a large, very quietly bedded area between the regional tectonic elements. This means that the corresponding uncertainties are also small, allowing for greater flexibility with regard to the layout of the repository.

FURTHER INFORMATION
– In detail: Flexibility

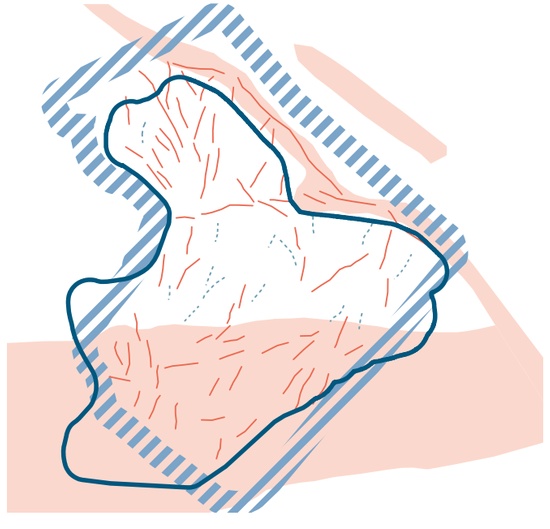
JURA OST

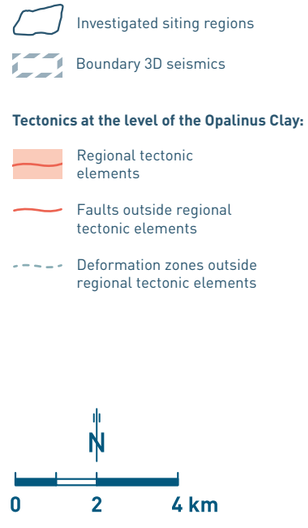


NÖRDLICH LÄGERN



ZÜRICH NORDOST





THE SITING PROPOSAL

"I am glad that the geological arguments clearly point to one region and I am convinced that we have found the best site."

MAURUS ALIG, COORDINATOR MAJOR PROJECTS SECTORAL PLAN STAGE 3

Maurus Alig already worked at the Mont Terri Rock Laboratory as a geology student. Later, he cleaned up contaminated sites in Argentina and was also involved in the dismantling of the hazardous waste landfill site in Kölliken. He joined Nagra in 2016.

REASONING BEHIND NAGRA'S SITING PROPOSAL

Fourteen years after the Sectoral Plan process was initiated, Nagra is in a position to announce which siting region is safest: the geological conditions in Nördlich Lägern are best suited to contain the radioactive waste in the long term. The quality and stability of the rock as well as the flexibility with regard to the layout of the repository are greatest here.

In 2018, the Federal Council assigned Nagra the task of conducting in-depth investigations of the three most suitable siting regions (Jura Ost, Nördlich Lägern and Zürich Nordost). Nagra performed this work in accordance with the criteria and requirements stipulated by the authorities.

The data basis is robust and the result is clear. From Nagra's point of view, it is now obvious that the Nördlich Lägern siting region is best suited for constructing a deep geological repository. Nagra will submit a detailed justification and comprehensive data basis together with the general licence applications.

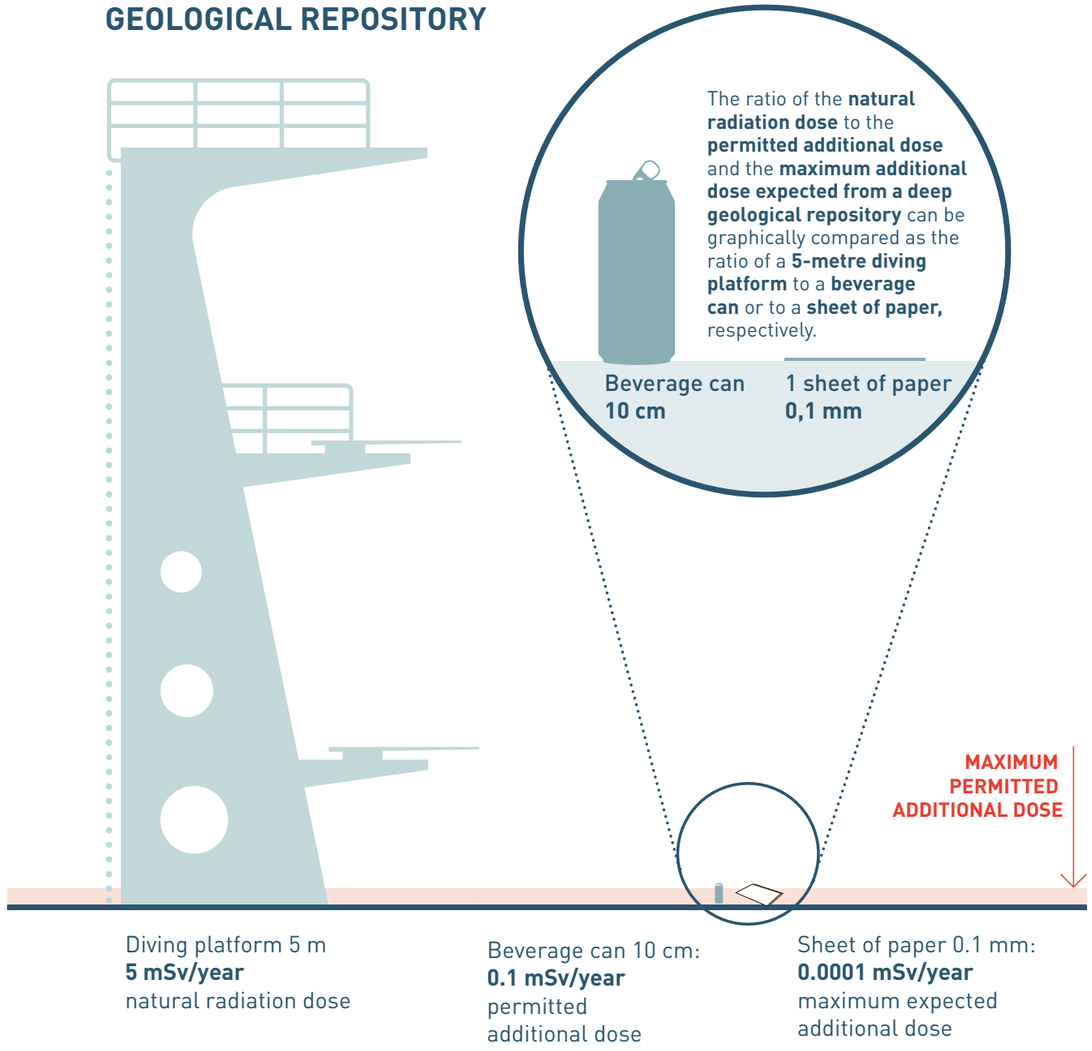
The site selection process has resulted in the identification of the most suitable regions in Switzerland in terms of their geological conditions. In conclusion, all three siting regions are suitable for hosting a deep geological repository as the geological situation and the rock properties are good throughout. Safety analyses were carried out to calculate how the radioactive substances would migrate in the three regions. The result in all cases was well below the protection objective of 0.1 millisievert per year – by a factor of a thousand. This is only a fraction of the radiation dose that we are exposed to from natural sources.

There are geological differences in the siting regions. The decisive factors are the quality and stability of the geological barrier as well as the flexibility in laying out the repository. For these aspects, the differences point in favour of Nördlich Lägern. For example, predictions with regard to erosion are most favourable in Nördlich Lägern even when considering highly unlikely scenarios involving altered river courses. Nördlich Lägern has the greatest safety reserves.

FURTHER INFORMATION

- Guideline ENSI-G03 of the Swiss Federal Nuclear Safety Inspectorate
- Brochure: Long-term Safety

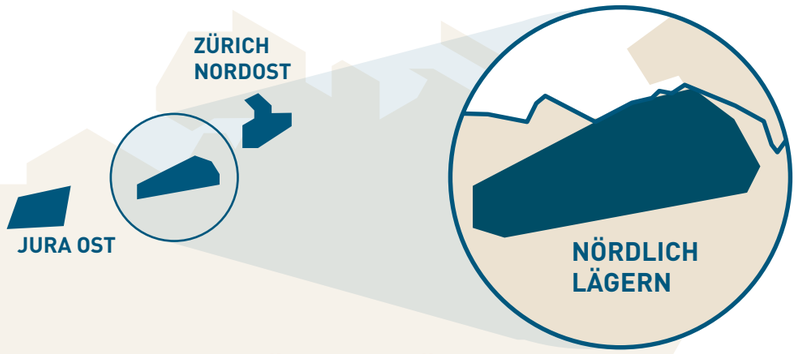
NATURAL RADIATION DOSE AND ADDITIONAL DOSE EXPECTED FROM A DEEP GEOLOGICAL REPOSITORY



AVERAGE RADIATION DOSE AND THE DEEP GEOLOGICAL REPOSITORY

The average natural radiation dose for a resident of Switzerland is around 5 millisieverts per year. Most of this comes from radon in our homes, cosmic radiation and food. In line with legal requirements, a person living directly above a deep geological repository may not be exposed to additional radiation exceeding 0.1 millisieverts per year. According to Nagra's calculations, the radiation level would increase by no more than 0.0001 millisieverts.

WHY NÖRDLICH LÄGERN?



CRITERIA GROUP	ALL THREE SITING REGIONS	THE ADVANTAGES OF NÖRDLICH LÄGERN	
PROPERTIES OF THE HOST ROCK AND THE CONTAINMENT-PROVIDING ROCK ZONE **QUALITY**	The homogeneous composition and the thickness of the clay-rich rocks satisfy the requirements in all three siting regions. The permeability is very low throughout. The consistently high content of clay minerals meets the prerequisites for self-sealing in all three regions, and the geochemical conditions are comparable in all cases. Due to the mineralogy of the clay-rich rocks, the retention capacity is high in all siting regions. The barrier function of the Opalinus Clay is very good in all three siting regions. In addition, the confining geological units contribute to the containment capacity and thus also to long-term safety.	**The geological barrier in Nördlich Lägern has the best waste containment capacity.** The porewater found in the Opalinus Clay and the surrounding clay-rich rocks in the Nördlich Lägern siting region is the oldest, indicating that the containment capacity of the geological barrier is best here. Contributing factors include the tightness of the rock, a large distance to water-bearing rock formations, the flow properties and conditions of these water-bearing rock formations and their connection to the surface.	
LONG-TERM STABILITY **STABILITY**	All three siting regions are geologically stable over very long time periods. In the highly unlikely scenario that strong tectonic forces should occur in the future, the Opalinus Clay would undergo ductile (plastic) deformation rather than fracturing. Even if small fissures were to form, the rock would quickly seal these on its own by swelling. All three siting regions provide a high level of protection from natural erosion processes caused by either glaciers or bodies of water. None of the three siting regions has relevant amounts of natural resources that could impact site selection.	**In Nördlich Lägern, the long-term stability of the geological barrier is greatest.** The geological barrier in this region offers the best protection from future erosion due its greater depth and the erosion-resistant rock formations located above the host rock.	
RELIABILITY OF GEOLOGICAL FINDINGS **FLEXIBILITY**	The geological conditions in the entire area of the siting regions can be reliably demonstrated and predicted based on available high-quality data. In Northern Switzerland, the Opalinus Clay has a remarkably uniform and even structure; the confining geological units are more heterogeneous. A comprehensive image of the geological underground in all the regions is available.	**Nördlich Lägern has the largest suitable area, thus providing the greatest flexibility for the layout of the repository.** The Nördlich Lägern siting region has the largest connected area with no indications of major faults. For this reason, flexibility with regard to the repository layout is greatest in this region.	
ENGINEERING SUITABILITY	Engineering challenges can be mastered in all three siting regions. New measurements on rock strength show that there are no relevant differences between the siting regions that would affect the construction, operation, monitoring or closure of the repository.		

Collaboration and exchange with the people from the affected regions are crucial to Nagra – here in the form of a guided tour of a drill site.

THE SURFACE FACILITY AT HABERSTAL

The surface facility for the repository is to be constructed in the Haberstal area in the community of Stadel. Nagra has selected this site in collaboration with the region and Canton Zürich.

The deep geological repository will be constructed, operated, monitored and finally closed from the surface infrastructure area. This is where the facilities and accesses will be located: for example in the form of shafts for construction and operation or for the supply of fresh air. The waste will be delivered here and prepared for emplacement in the repository. Administration buildings and workshops complete the overall surface infrastructure. These facilities and structures will be constructed in stages. Most of them will be dismantled again after a few decades when they are no longer needed.

When it comes to placing the repository underground, safety will be determined by geological considerations. The site is therefore selected in accordance with the safety-based criteria set out in the Sectoral Plan. The site for the surface facility was identified together with the region. Here, safety mainly relies on the layout of the installations rather than on geology or the exact location of the site.

The Federal Government has the lead in the participation process, during the course of which regions and cantons are invited to raise their interests and concerns. Starting in 2012, representatives of the Nördlich Lägern siting region and Canton Zürich discussed various sites for the surface facility and decided in favour of the area near Haberstal. Nagra has accepted this recommendation and plans to construct the surface facility there – without the encapsulation plants.

FURTHER INFORMATION

- Vorläufige Planungsstudie (Nagra Work Report NAB 22-05, in German)
- Vorschläge zur Konkretisierung der Oberflächeninfrastruktur der geologischen Tiefenlager (Nagra Work Report NAB 19-08, in German)
- Module eines geologischen Tiefenlagers (Nagra Work Report NAB 22-35, in German)
- Regional participation – an overview / Swiss Federal Office of Energy
- Nördlich Lägern Regional Conference (in German)

VISUALISATION OF THE SURFACE FACILITY

INITIAL WORK FROM 2034

Construction of the surface infrastructure will begin around 2034. At the same time, the facilities for the underground geological investigations will be constructed. In parallel, two shafts will be excavated down to the depth of the host rock. Following this, further detailed investigations will be conducted, for example, on the Opalinus Clay at the disposal level.

CONSTRUCTION AND WASTE EMPLACEMENT (2045-2075)

The facilities will be expanded to become part of the deep geological repository: a third shaft will be constructed, through which the radioactive waste will be transported to the disposal level, and the repository section for low- and intermediate-level waste will be excavated. During this construction phase, the surface facility will have to include areas for construction site installations, storage areas for equipment and construction materials as well as landfills for excavated material. Emplacement operations for low- and intermediate-level waste will start in 2050. The repository section for high-level waste will be constructed from 2055, and emplacement will begin in 2060. With the end of emplacement operations, the drifts and caverns will be closed with a first seal.

MONITORING PHASE FROM 2065 AND FINAL CLOSURE AROUND 2125

To allow for long-term monitoring, the repository will remain directly accessible for a certain time period. In line with current planning, the repository will be closed in stages. The accesses to the emplacement rooms will be backfilled and sealed. Should future generations decide to go ahead with the final closure of the repository, this would, according to present-day planning, take place around 2125. Following this, the last remaining surface facilities will be dismantled.

ENCAPSULATION PLANTS AT ZWILAG

The encapsulation plants will be constructed on the terrain of the Zwilag interim storage facility in Würenlingen. This decision is mainly supported by synergies with existing facilities as well as by environmental aspects.

Before radioactive waste can be emplaced in a deep geological repository, it has to be packaged in disposal containers. Encapsulation plants will therefore be needed for all waste categories, including spent fuel assemblies. These encapsulation plants can either be located at the surface facility in Stadel or at the Zwilag interim storage facility in Würenlingen.

Placing them at Zwilag has several advantages – here, it is possible to benefit from synergies with the existing infrastructure. The encapsulation plants can be constructed as extensions to the existing nuclear industrial installations. The immediate proximity to the Swiss Federal Interim Storage Facility is a further advantage. Until emplacement in the repository, all of Switzerland's radioactive waste will be held in a 1.5-kilometre radius around Zwilag, where it will be packaged for disposal. The Zwilag site also makes sense from environmental and spatial planning perspectives: the surface facilities can be constructed in a more compact manner and will require fewer resources overall.

FURTHER INFORMATION

- Zwilag website
- Begründung Standortwahl Verpackungsanlagen (Nagra Work Report NAB 22-27, in German)
- Vorschläge zur Konkretisierung der Oberflächeninfrastruktur des geologischen Tiefenlagers, Standortspezifische Vorschläge (Nagra Work NAB 19-08, in German)
- Verpackungsanlage hochaktiver Abfälle: Vor- und Nachteile verschiedener Standortvarianten (Nagra Work Report NAB 20-14, in German)
- Jura Ost Regional Conference (in German)

The proximity to other nuclear installations (Beznau interim storage facility, Paul Scherrer Institute, Swiss Federal Interim Storage Facility) bundles competences and resources for handling nuclear materials at the Zwilag interim storage facility.

MAKING USE OF SYNERGIES

Zwilag has more experienced staff on site to handle radioactive waste. For example, a hot cell for repackaging already exists there. Another benefit of the close proximity of the nuclear installations to each other is increased flexibility in overall operational procedures, including the provisioning halls. In addition, as some of the infrastructure already exists at Zwilag, the construction of certain buildings can be avoided. To package low- and intermediate-level waste, for example, it will only be necessary to increase the capacity of the existing facility. Thanks to its proximity to Zwilag, the encapsulation plant for high-level waste can be designed on a smaller scale.

The site is already the competence centre for the conditioning and packaging of radioactive waste. By locating the encapsulation plants at Zwilag, it is possible to benefit from synergies with regard to safety-relevant operational procedures.

SURROUNDINGS AND ENVIRONMENT

The Zwilag site already has an industrial character, and the encapsulation plants will blend in without considerably changing the landscape. The encapsulation plants will require less space for the surface infrastructure if they are constructed at Zwilag rather than near Haberstal. As a result, intrusion into the landscape can be reduced, and less forest will have to be cleared.

ORGANISING THE REQUIRED WASTE TRANSPORTS

Regardless of where the encapsulation plant will eventually be constructed, all radioactive waste will have to be transported from the greater Zwilag area to the deep geological repository. The disposal containers, especially those for high-level waste, can hold significantly less waste than present-day storage containers. For this reason, placing the encapsulation plants at the Zwilag interim storage facility will result in an increase of the number of waste transports by around 50 percent.

However, transports such as these are routine and have been carried out without problems for decades in Switzerland and other European countries. Most of these transports take place as regular road transport by lorry or heavy vehicle, and a small portion is carried out as special transport secured by a police escort. On average, a transport of radioactive waste will take place every one to two weeks over a period of fifteen years.

THE NEXT STAGE

“Nagra has been conducting research since 1972. Our siting proposal rests on this foundation. But that does not mean that the researchers here at Nagra will be resting. We will continue our research and keep learning – and eventually construct a state-of-the art repository.”

IRINA GAUS, HEAD OF RESEARCH & DEVELOPMENT

The hydrogeologist was involved in underground European research projects for many years. Since 2007, Irina Gaus has applied her work experience at Nagra.

NEXT STEPS

Nagra will continue its research – until the final closure of the repository. The authorities will continue to review the project, and society will also have to assume responsibility. Initial construction work on site will begin a good ten years from now.

Over the next two years, Nagra will prepare its general licence applications and technical documentation for the deep geological repository in Nördlich Lägern and for the encapsulation plants at the Zwilag interim storage facility in Würenlingen. After the applications have been submitted, they will be reviewed by the authorities. The decision to approve the licences will be made by the Federal Council and the Federal Parliament and, in case of an optional referendum, the Swiss electorate. At least ten years will pass before initial construction work for the underground geological investigations can begin. Additional licences will be required later, for example for the construction and operation of the repository and finally for its closure. The authorities will thus continue to monitor and review the project.

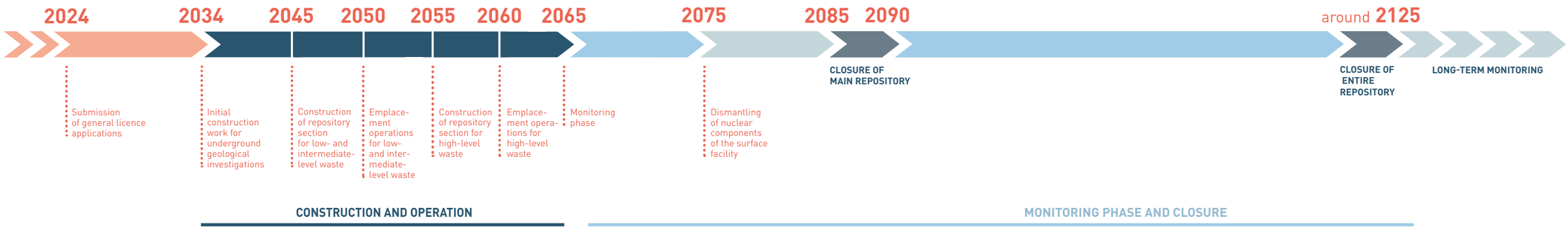
Construction activity until repository closure one hundred years from now will vary in intensity. An initial, intensive phase will take place around 2034 when the shafts will be constructed. A varying level of construction work will follow until repository closure.

Nagra is obliged by the authorities to continue its research until the closure of the repository and to take into account technological progress. While Nagra's experts are convinced that they could already construct a safe repository today, they are aware that further optimisation is possible: technology is constantly evolving, and the deep geological repository should benefit from this. The disposal canister for high-level waste, for example, has already been designed to remain intact for at least 10,000 years – which is ten times longer than required by law. Nevertheless, specialists at Nagra are researching ways to further optimise this canister. Progress in the fields of robotics and automation will also impact how waste will be emplaced and, if necessary, retrieved.

Nagra conducts its research in close collaboration with universities and foreign waste management organisations and also benefits particularly from countries whose repository projects are more advanced than Switzerland's. Collaboration across international borders is key to making the deep geological repository for radioactive waste a success in Switzerland. Aside from this international exchange between scientists, the scientific community must also work together with politicians and society. With a successful collaboration, the issue of deep geological disposal can be solved, relieving future generations of the obligation to deal with it.

FURTHER INFORMATION

- Waste Management Programme 2021 of the Waste Producers (Nagra Technical Report NTB 21-01)
- The Nagra Research, Development and Demonstration (RD&D) Plan for the Disposal of Radioactive Waste in Switzerland (Nagra Technical Report NTB 21-02)
- RD&D Vision Document Nagra
- Research at the Grimsel Test Site
- Research at the Mont Terri Rock Laboratory
- Research Platform for European Waste Management Organisations (IGD-TP)
- European Joint Programme on Radioactive Waste Management (EURAD)
- The First Underground Warren for Disposing of Spent Nuclear Fuel / The Economist



IMPRINT

Published by:
National Cooperative for the
Disposal of Radioactive Waste
Hardstrasse 73
5430 Wettingen
Switzerland

Editorial office: Nagra

Proofreading: Inés Flück, sprach-art (original German version)

Print shop: bm Druck AG

Circulation: 4,500 copies

Publication date: September 2022

Issues available through: Nagra (info@nagra.ch)

This is an English translation of the original
German version. A French translation is also available.
The German version is binding.

All depicted persons are employees or contractors of Nagra.

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