CERKNO GEOTHERMAL EDUCATIONAL TRAIL

Let's go on a walk around the Cerkno Region!

LET'S GO ON A WALK AROUND THE CERKNO REGION!

The Cerkno Region is a diverse part of the world surrounded by peaks offering luxurious views and mysteriously adorned with green valleys, vast woods and sunlit plateaus.

Cerkno lies in the Pre-alpine world in the western part of Slovenia, secured with numerous dells, creaks and peaks; it borders on the Primorska Region and the Gorenjska Region, at the point where the Dinaric world transitions into the Pre-alpine world. In the past tectonic activity was very strong in these parts, this is why the Cerkno Region is one of the areas with the most diverse geological composition in Slovenia. This can be noticed simply by taking a walk along the nearby trails, high plateaus, mountains and hills in the immediate vicinity of Cerkno, Lajše, Brdce, Lamk, Medvejk … and elsewhere. On walks you stumble across different types of rock which differ in structure and colour.
We can observe where and from what rocks springs come to the surface, where the slopes are sliding, how layers and cracks lay in space. Just in the immediate vicinity of Cerkno 28 different geological units can be found. Due to its diverse geological composition the area offers many potential uses of geothermal energy.
Do you want to know which rocks lay 2, 5, 10, 50, 100 or even 1000 meters below the surface? How much geothermal energy is stored in different rocks and how can we use it?

Go on a walk with us on the first geothermal educational trail in Slovenia.

CERKNO GEOTHERMAL EDUCATIONAL TRAIL

The Municipality of Cerkno has a long tradition of exploiting geothermal energy. This is why the first geothermal educational trail in Slovenia was set here, as part of the project GRETA. Geothermal energy is the energy stored in the form of heat under the hard Earth's surface already at a depth of 0,8 m and then deeper. The educational trail gradually leads us from the Earth's surface deeper and deeper into the ground, showing us the characteristics of geothermal energy at depths of 20, 100 and finally 2000 m below surface. We get to know different rock types that the deepest borehole penetrated at different depths. We learn how well rocks conduct heat and how to calculate the approximate amount of available of energy, and how to harness it.

INTERMITTENT SPRING OF ZAGANJALKA NEAR STRAŽA

Springs bring geothermal energy to the surface of the Earth.

The majority of springs are recharged by rainfall infiltration into the soil. Their temperature corresponds to the average annual air temperature. The water can, however, come from greater depths, where it is further warmed by the Earth's internal heat. The water from such springs may be warmer in winter than in summer. Alternatively, it may have a constant temperature as a consequence of a prolonged stay beneath the Earth's surface. Commonly, spring water has a temperature corresponding to the average annual temperature of the place where it springs to the surface. If the average annual temperature of the place is 9 °C, the spring water will have approximately this temperature, too. Hence, it feels cold in summer and warm in winter. This also reflects a specific aspect of geothermal energy: in winter we use it for heating, and in summer for cooling.

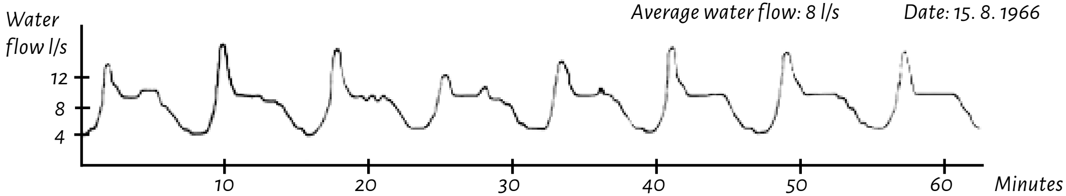
Spring Zaganjalka

Fracture in dolomite beds from where the water outflows.

The specificity of the intermittent spring of Zaganjalka is the occasional rhythmic change in water flow from a fissure in the dolomite rock wall, which is an interesting Karst phenomenon.

The reason water appears at the site of the spring can be traced to geology. The water comes to the surface at the contact between the fractured dolomite beds (above) and marlstone beds (below). That contact is not visible, because it is covered by a scree. Marlstone has a lower permeability and prevents ground water from flowing below the surface, so that it comes to the surface. The water temperature is about 8.5 °C. At average water levels, the spring is triggered every 8 minutes; at low levels every minute.

The example shows the triggering of water flow varying between 4 and 16 l/s. In the event of high water levels, water flow may increase to several dozens of litres per second.



The graph shows measurement results of water flow triggered, varying between 4 and 16 l/s (Podobnik, 1968).

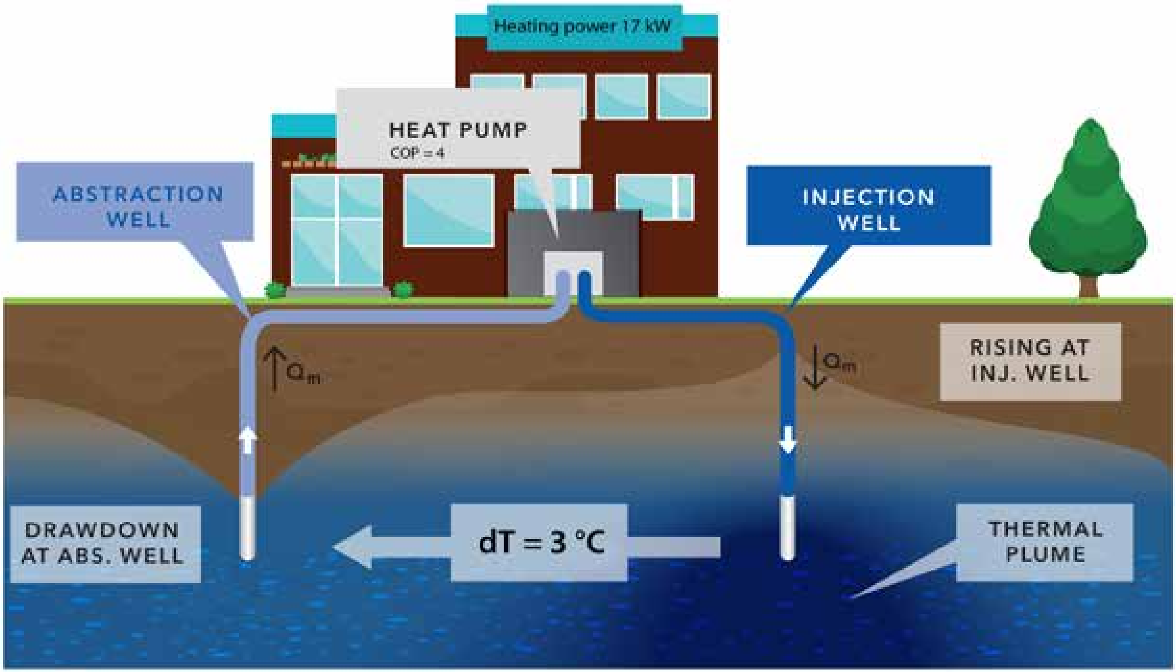
Information table at Zaganjalka spring.

Concrete sill at the spring

The water from the springs can be used to heat and cool houses or, for instance, to heat a pool.

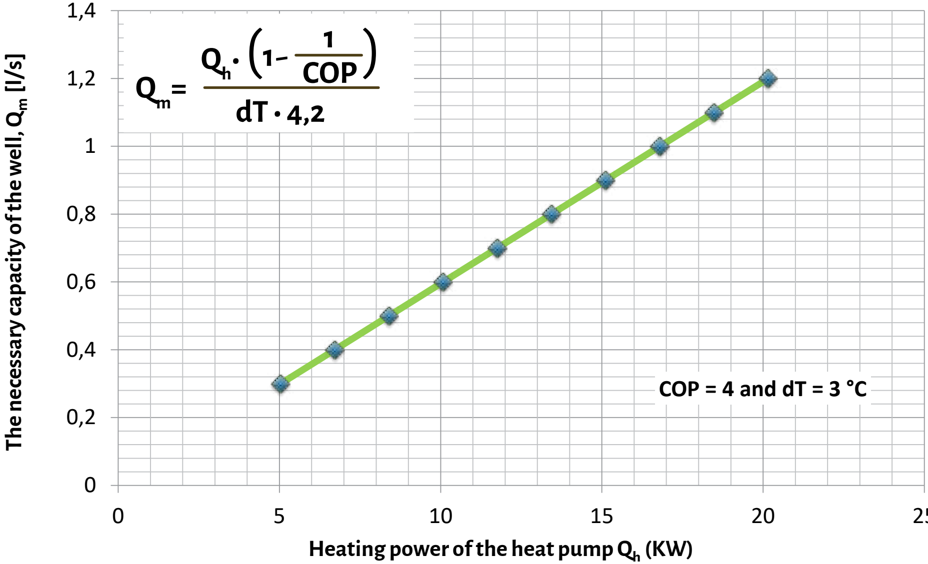
The springs are rarely found near houses and hamlets, and their water flow can fluctuate significantly (draught, turbidity), which prevents them from being exploited for heating purposes using heat pumps. Regardless of these limitations, they represent a highly suitable source of thermal energy if planning is carried out properly, especially as a supplementary source of heating for pools in summer.

If no spring is nearby, it should be checked whether an aquifer with sufficient water flow is present underground. In this case, we can pump the groundwater from the aquifer, take the heat or cold from it and then re-inject it back to the aquifer by way of a sinking well.



Example of assessment of required water flow for water/water heat pump

If 1 l/s of water from the spring (Q_m) were used for heating and 3 °C (dT) were extracted with a heat pump (COP = 4), this would generate a heat output (Q_H) of 17 kW. This output can be sufficient to heat two relatively low energy efficient single-family houses.



Overflow from spring Zaganjalka

The graph shows the necessary capacity of the well with respect to the heat output of a heat pump with a coefficient of performance of 4. Thereby, it is assumed that the difference in temperature between the pumped and recycled underground water is 3 °C.

How to get to the intermittent spring Zaganjalka?

From the starting point we drive in the direction of Idrija. Roughly 500 m from the crossroad where we turned towards Idrija we go left (Straža 5). We reach the first houses of the village (Straža 19), continue straight on macadam road and after about 2 kilometres we reach the information sign Zaganjalka. Point 6 – Na Straži is located at the crossroad with the main and side road next to Straža 5. At this Point you get an insight into the rich variety of rocks in this area.

The Zaganjalka creek.

STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Spring Zaganjalka (660 m)
DISTANCE: 8.120 m

20 min

ECO-ENERGY PARK WITH LOG CABIN DISPLAYING RENEWABLE ENERGY SOURCES AT THE PRIMARY SCHOOL

Shallow geothermal energy is renewed by solar radiation and the Earth’s heat flow.

Daily changes in air temperature are noticeable only down to a depth of 1 m below the soil surface. Seasonal fluctuations reach down to a depth of about 20 m. Deeper down, solar radiation has no impact – temperatures do not fluctuate, but only rise with increasing depth. Down there, the temperature is only dependent on the Earth’s heat flow and the thermal conductivity of the rocks.

In winter, air temperatures can drop far below zero degrees Celsius, but soil temperature deeper than 2 m will not fall below 0 °C. A similar situation can be observed in summer. While outdoor temperatures may reach 30 °C and more and we are really hot, temperatures at a depth of 2 m below the surface will not rise above 15 °C. 20 m below the surface, the temperature is constant and corresponds to the average annual air temperature. For this reason, good use can be made of shallow geothermal energy for heating or cooling – from a depth of 1.5 to 2 m onwards.

State-of-the-art heat pumps allow for the exploitation of shallow geothermal energy anywhere on Earth.

Get to know the log cabin of renewable energy sources.

The log cabin in the educational eco energy park shows different types of renewable energy sources.

One of them is shallow geothermal energy.

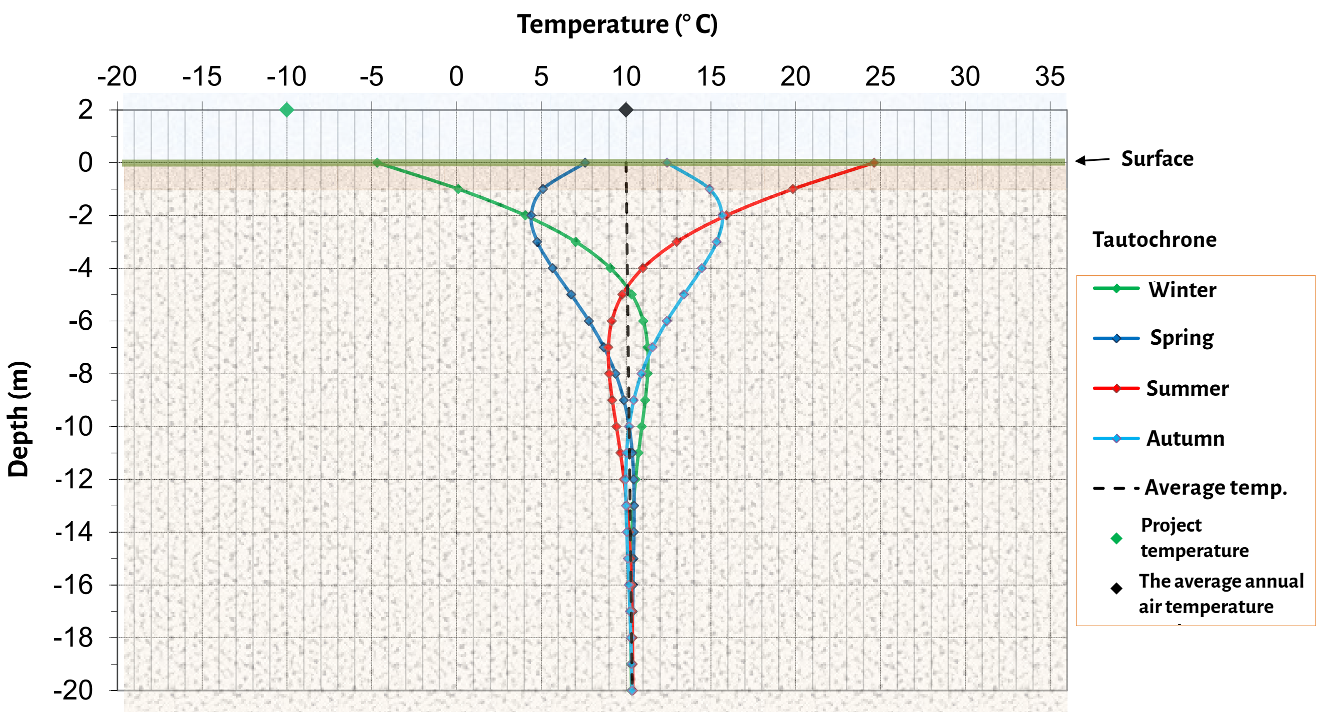
On the screen in the log cabin, you can observe, in real time, the differences between the air and soil temperature at depths of 10, 50 and 100 cm.

- Soil temperature fluctuates significantly less than air temperature. For this reason, geothermal heat pumps are already efficient at shallow depths below the surface.
- It can be seen that the soil is colder than the ambient air in summer, and significantly warmer than the ambient air in winter. Hence, geothermal energy can be used both for heating and cooling.
- If we look at a larger set of data, we can see that in autumn the soil at a depth of 1 m is warmer than in summer. This means that the soil heats up and cools down with a time delay: The impact of more intense solar radiation to the soil surface does not become apparent until after the end of summer. For this reason, heat can be stored in the soil during summer, and used later during the heating period.

The results of soil temperature measurements at a depth of 1 m can be compared to the results of temperature measurements in the borehole Ce-1/94 at Rajda, at a depth of up to 100 m. This proves that the impact of solar radiation only reaches down to very shallow depths, while deeper down the Earth's heat flow coming from the Earth's crust, mantle and core is the dominant force.

A display in log cabin (above) shows the temperatures of shallow subsoil at a depth of 10 cm, 50 cm, and one meter below surface.

Temperature flow down to a depth of 20 m -tautochrones calculated for Cerkno from temperature wave on the surface in 2016.



The average annual air temperature is about 9 °C, fluctuating between -20 and +36 °C over the year. The average annual soil temperature is about 1 °C higher, i.e. approximately 10 °C. At a depth of 20 m, the temperature is constant throughout the year, and only subject to long-term changes related to climate change.

By installing a horizontal heat exchanger at a depth of a mere 1.5 to 2 m, we can heat a building with shallow geothermal energy.

As the hamlets are relatively dispersed, sufficient space exists between the buildings to install shallow horizontal heat exchangers. Heat exchangers consist of pipes laid underground. The fluid in the pipes transmits heat from the soil to the heat pump.

To install and use such heat exchangers, the soil must be suitable for excavation to a depth of at least 1.5 m. Preferably the soil should be moist and cohesive (not loose). In this case it can be assumed that we will be able to obtain a heat output of 24 W/m^2 for up to 2100 operating hours per year. To heat a building with 15 kW, this output is divided by 24 W/m^2, and we obtain the necessary surface of 625 m^2 for the installation of the heat exchanger, i.e. 25 x 25 m if the excavation is executed as a square shape.

How to get to the eco-energy park at the primary school of Cerkno?

From the starting point we turn left on Bevkova ulica 26 until we reach Primary School Cerkno on the right. On the right side in front of the school's entrance in the eco park we see a log cabin of renewable energy.

STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Log cabin of renewable energy (324 m)
DISTANCE: 514 m

2 min

7 min

GEOTHERMAL BOREHOLE Ce-1/94 – AT RAJDA

The soil temperature in the Cerkno region rises by about 2 °C for each 100 m of depth

A 134 m deep geothermal borehole Ce-1/94 is located in the south-eastern part of Cerkno, at Rajda, on a meadow below the main road leading to the villages of Planina and Kladje.

The geologists predicted with a high degree of probability that the borehole at this site would penetrate rocks of low permeability with no water inflow down to a depth of at least 100 m. This is necessary in order to measure the temperature rise with increasing depth and therefore reliably predict temperatures at greater depths.

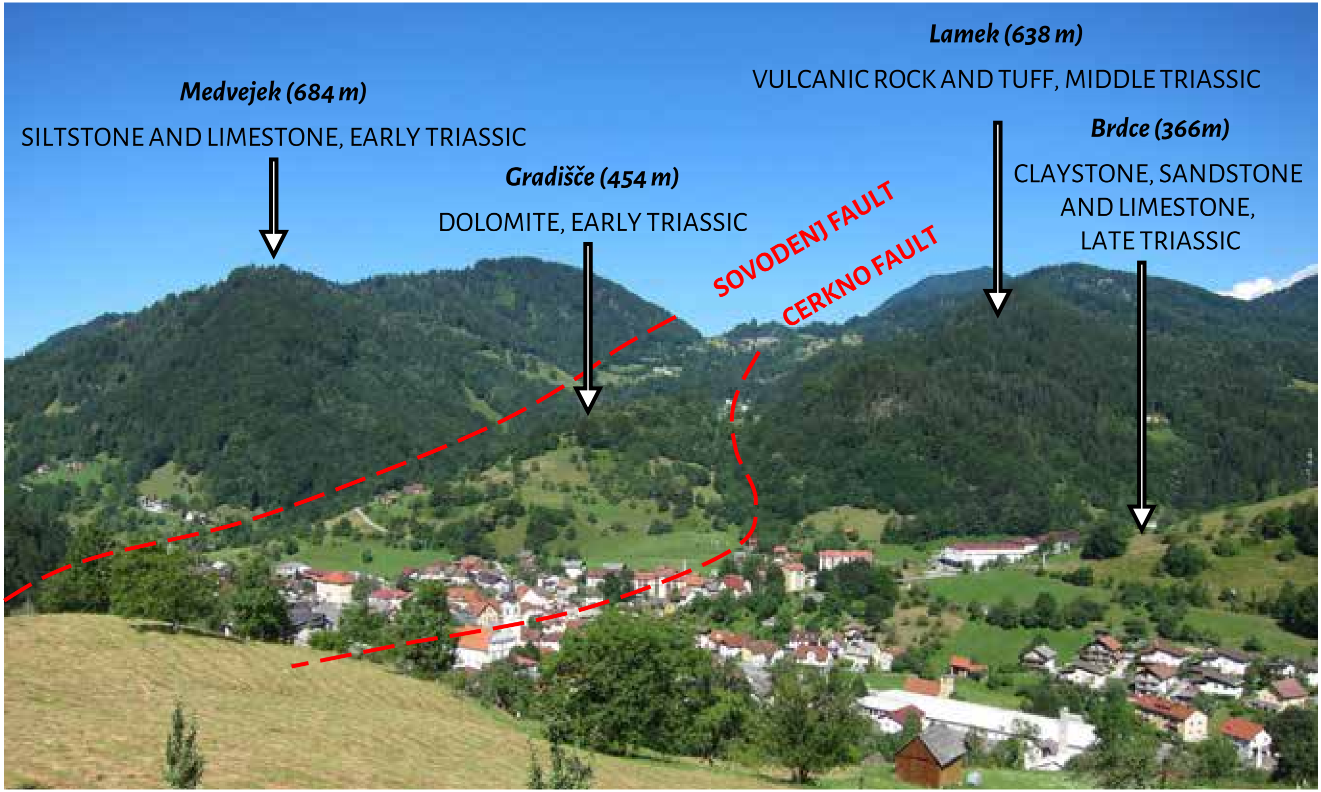
As expected, the borehole penetrated the shaly claystone and quartz sandstone (Carboniferous period). No major water inflow was observed although the underground water level is not at all deep below the surface.

On the basis of measurements at different depths, it was found that temperatures rise by 1.94 °C/100 m (the temperature gradient is 19.4°C/km). An average thermal conductivity of 2.9 W/(m·K) was calculated in the sequence of rock strata penetrated. The temperature gradient multiplied by the thermal conductivity of the rocks provides the Earth's heat-flow density, which at this location amounts to 0.056 W/m^2 or 560 W/ha. These are the essential geothermal parameters that describe the natural potential of shallow geothermal energy. Based on this data, the geologists were able to predict with sufficient reliability the expected temperature at greater depths in order to plan the deep borehole at Hotel Cerkno.

The geothermal borehole Ce-1/94 will be useful in the future too, especially to monitor the development of climate change, which will also be reflected in changes of soil temperature at depths of more than 20 m as well as in the geothermal gradient.

Variation of geothermal parameters depending on geological features

If we go somewhat higher up, starting from the Rajda site towards the village of Čeplez, a beautiful panorama opens up with a view of Cerkno against the backdrop of the surrounding hills.

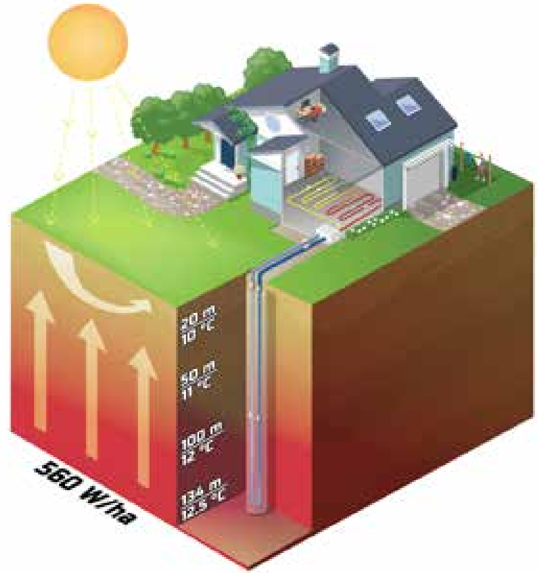


The visible features of the surface are, to a great extent, conditioned by tectonic processes and two major geological faults – the Sovodnje fault and the Cerkno fault. Both stretch far beyond the municipality of Cerkno, in north-westerly and south-westerly directions. At the faults, geological strata of different ages and compositions can come into contact in a small area: limestone, dolomite, sandstone, claystone and also volcanic rocks. As a result, the geothermal parameters are highly variable in these areas. The least variable is the density of the Earth's heat flow, because it comes from great depths.

Exploitation of geothermal energy with borehole heat exchangers

The data from geothermal boreholes is highly important in planning the exploitation of shallow geothermal energy with geothermal probes. A borehole heat exchanger (BHE) is a vertical heat exchanger installed in a borehole. It is a piping loop system filled with a fluid. The fluid circulates in the pipes with the help of a circulation pump, thereby extracting heat from the rocks and transferring it to the heating or cooling system.

Typically, boreholes of 100 to 200 m in depth are drilled for this purpose, but they may be less deep or deeper.



How to reach the geothermal borehole Na Rajdi?

From the starting point we go to Glavni trg. At the building on Glavni Trg 3 we turn right and continue straight until we reach the crossroad with the main road. Here we turn left towards Kladje. After about 700 m there is a narrow asphalt road that leads to a private land. We suggest that you leave the car by the road (there is space for one car) and continue on foot to the borehole which is 80 m away.

Today the cap of the geothermal borehole Ce-1/94 has a grass cover in order not to obstruct mowing.

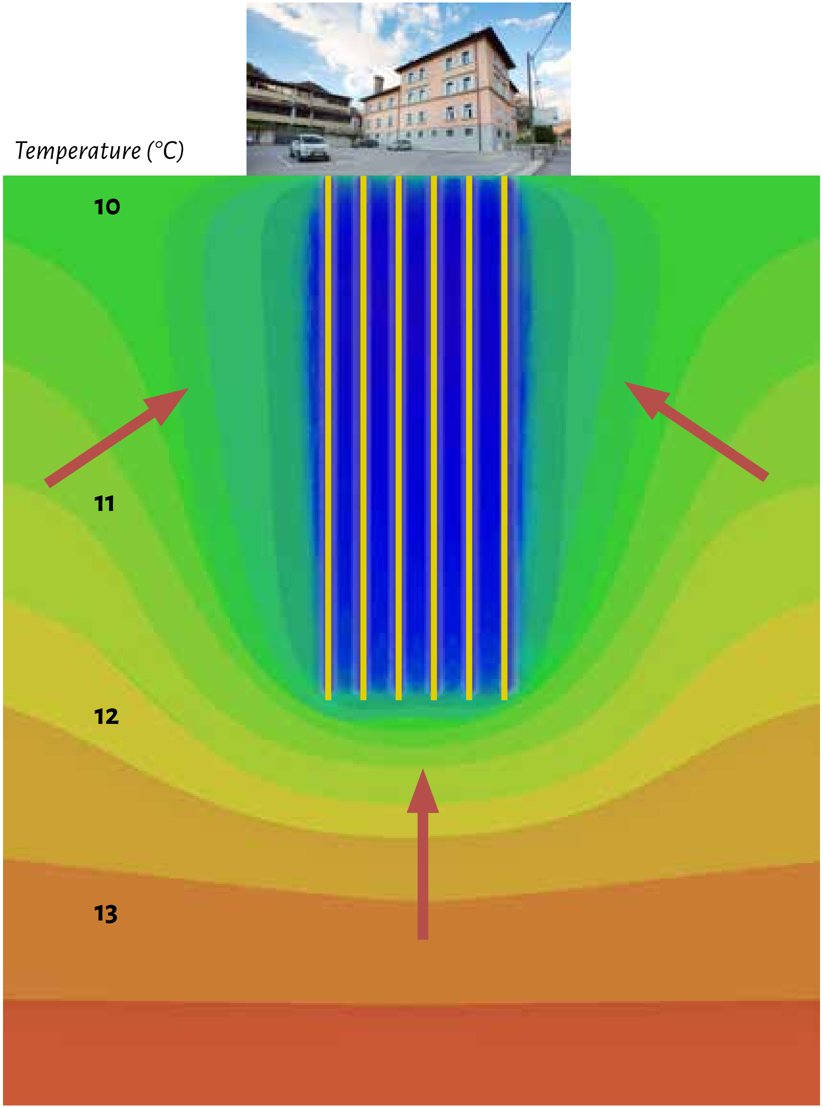
STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Geothermal borehole (391 m)
DISTANCE: 1.300 m

5 min (car) 20 min (walking)

4 BOREHOLE HEAT EXCHANGER FIELD AT THE MULTI-PURPOSE CENTER OF CERKNO

Using boreholes down to a depth of 100 m we can extract sufficient shallow geothermal energy to heat and cool large buildings.

The extraction of significant amounts of shallow geothermal energy requires a relatively deep borehole or several shallow boreholes. Beneath the parking space of the multi-purpose center of Cerkno, 12 borehole heat exchangers (BHEs) have been installed in boreholes at a depth of 96 m, separated from each other by a distance of about 6 m. The geothermal field generates 128 MWh of heating energy and 4 MWh of cooling energy per year. This saves more than 11,000 litres of heating oil per year. The rooms of the building are heated and cooled with underfloor, radiator and convection heating.



The heating energy extracted from the rocks by the borehole heat exchangers is recovered from greater depths and the surroundings of the borehole heat exchangers.

A heat pump uses electrical energy to raise the natural temperature of rocks or underground water to the temperature required for heating in the building (e.g. between 25 and 35 °C for underfloor or 45 to 65 °C for radiator heating).

The Primary School and the multi-purpose center of Cerkno are public buildings whose heating systems are connected to biomass and shallow geothermal energy.

The advantage of shallow geothermal energy systems lies in the fact that heat surpluses arising during cooling in summer can be stored in the ground and later used in the heating season. This further makes them significantly more efficient. Therefore, these systems represent an interesting solution in combination with other sources of energy.

The following is an example of combined heating systems from different renewable sources of energy: Biomass in the elementary school of Cerkno and shallow geothermal energy in multi-purpose center of Cerkno. The biomass boiler covers needs at peak times and provides hot water heating, so the geothermal system has more excess energy for heating in spring and autumn and can provide cheaper energy to cool neighbouring buildings in summer.

How big must a shallow geothermal catchment area be, by rule of thumb?

First, we must assess the required heating power by multiplying the difference between the interior and exterior project temperature* by the total heat transmittance and the surface of the building's shell. If we assume that the interior project temperature is 20 °C, and the exterior project temperature -13 °C, we get a difference of 33 K. We multiply this by the value for heat transmittance, which is about 1 W/(m^2 K) for older buildings with ordinary insulation, and the building's shell of 440 m^2 (e.g. for a floor plan surface area of 100 m^2). We get a heat output of Q_H = 14.5 kW. Considering the heat pump (with a coefficient of performance COP = 4) provides one quarter of the heating power, we need to install a borehole heat exchanger with an output power Q_{GE} of 10.9 kW. If we install the borehole heat exchanger in the sandstone layer, we can assume a specific heat extraction rate of 65 W/m. In this case, the borehole needs to be 168 m deep. Alternatively, two more shallow boreholes could be drilled.

** The project temperature corresponds to the average lowest long-time annual temperature of the three-day average daily minimum temperature.*

How to get to the field of probes next to the multi-purpose center of Cerkno?

From the starting point we head towards Glavni trg where we turn left into Bevkova ulica, continue straight to the Cerkno Museum and the multi-purpose center of Cerkno. We walk across the parking lot to the information board.

STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Multi-purpose center of Cerkno (VCC) (324 m)
DISTANCE: 480 m

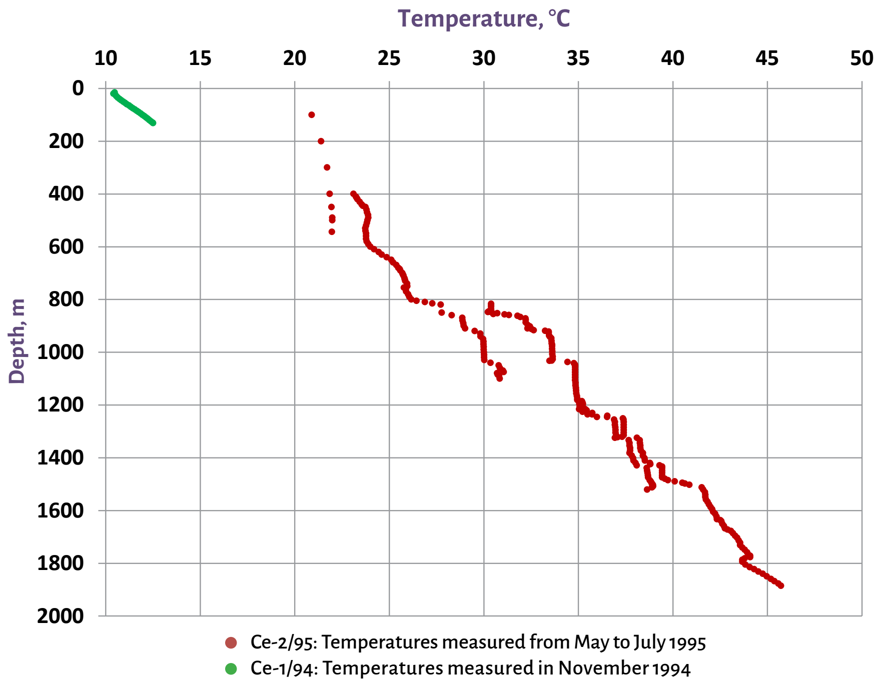
2 min (by car)

6 min (on foot)

Extraction of geothermal energy from a depth of more than 300–400 m is called deep geothermal energy production.

The borehole Ce-2/95 at Hotel Cerkno is the deepest operating geothermal borehole in western Slovenia and the second deepest in all of Slovenia. It is 2,004 m deep. Thermal water with a temperature of 27.8 °C rises to the wellhead of the borehole under its own artesian pressure of 27 bars.

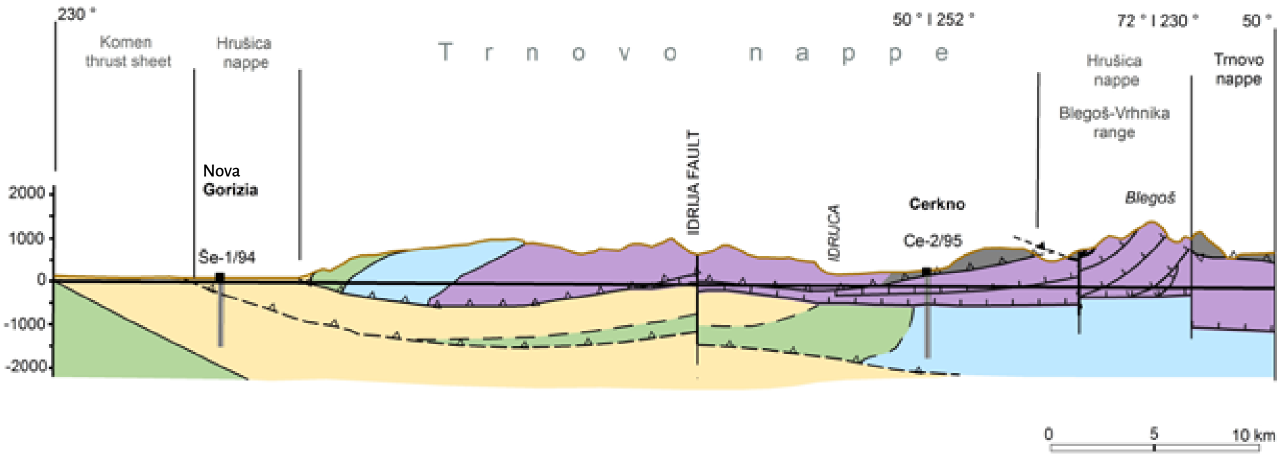
Temperatures measured in the C-2/95 and C-1/94 boreholes in Cerkno



Temperatures at depth 2,004 m are around 48 °C.
The largest influx of thermal water into the borehole occurs at depths of 850 to 1.150 m.

The transversal geological cross-section from the village of Šempeter pri Novi Gorici to Cerkno shows thrust faults and ages of geological units down to a depth of 2 km.

The main recharge hinterland area consists of the extensive dolomite aquifer in the Blegoš hilly massif.
During the formation of the Dinarides and the Alps dozens of millions of years ago, the geological strata collided, broke up, and slid over each other. Several thrust sheets formed as a result. The rocks in the surroundings of Cerkno and below are part of the Trnovo and Hrušica nappes. The geothermal aquifer lies in these strata and was drilled by the borehole Ce-2/95 at a depth of almost 600 m.



Top-quality thermal water is also directly used to fill up pools.

As the temperature of the water from the borehole is above 20 °C, we can speak of thermal water. Springs with a water temperature above 20 °C are rare in Slovenia and are of special economic value; therefore, their exploitation is subject to a concession fee.

The highest possible heat power of the borehole is 1.5 MW. This occurs at the highest theoretical water ouflow of 28 kg/s and abstracting the heat from the water by cooling it down from 27.8 °C to 15 °C. Today, up to 140,000 m^3 of thermal water is exploited per year. In 2017, a total of 1,895 MWh of energy was extracted from the borehole, corresponding to 163 tons of oil.

Due to its favourable temperature, chemical composition and very high quality, the water from the Ce-2/95 borehole can be directly used to fill pools. Such quality is exceptional in boreholes that are so deep, and is the result of the excellent recharge dynamics from the Blegoš massif.

Before discharging the water back into the environment, it is abstracted through a system of heat pumps with a rated power output of 680 kW to heat premises, provide hot tap water and heat pool water.

How to get to the geothermal borehole next to Hotel Cerkno?

From our starting point we head towards Glavni trg. We continue down Bevkova ulica until we reach the Municipality (Bevkova ulica 9), where we turn left into a meadow. At the end of the meadow (by the river Cerknica), there is a hut, we walk up to it.

STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Hotel Cerkno borehole (319 m)
DISTANCE: 350 m

1 min

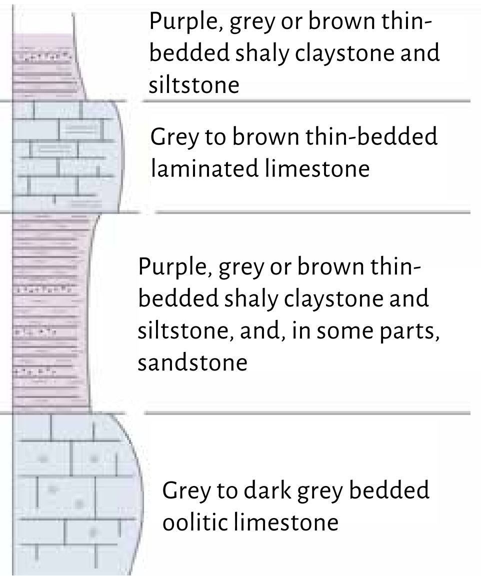
5 min

6 CROSS-SECTION OF GEOLOGICAL STRATA THAT FORM THE TERRITORY OF THE CENTRAL AND SOUTHERN PART OF THE CERKNO REGION – THE HAMLET OF STRAŽA

The thermal conductivity of the rocks is the most important factor in the exploitation of shallow geothermal energy; therefore, we must have a good knowledge of the geological conditions of the area.

In the deep road cutting, near the hamlet of Straža at the entrance to the Zaganjalščica valley, Lower Triassic rocks dating from about 250 million years ago can be found. Their lithological diversity indicates that a good knowledge of the geological conditions in the region is required for the planning of the shallow geothermal energy catchment area.

In the road cutting, alternating layers of carbonate rocks (limestone) with a thickness of up to 2 m, and finely grained clastic sedimentary rocks (claystone, siltstone and sandstone) are exposed. The claystone and siltstone show violet colours and occur in thin, distinct layers. The rock structure is often shaly. Grey and brown limestone occurs in 10 to 40 cm-thick layers. It is composed of fine carbonate grains that formed on what was once the floor of a shallow ocean. The rock strata are slightly folded and dip at a gentle angle of 10–25° toward the west and north-west.



These rocks are rather common in the Cerkno region. They form the largest areas in the very central and southern part of the region.

Rock thermal conductivity and rock heat extraction are conditioned by rock composition.

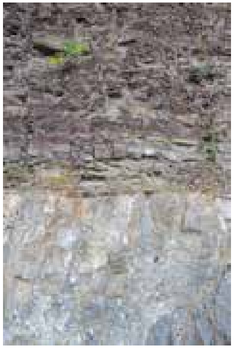
Within the sequence of clastic rock, we may expect a thermal conductivity range of 1.8 W/(m·K) typical of claystone, to 3.4 W/(m·K), measured in a sandstone sample nearby. In the Lower Triassic limestone, a thermal conductivity of about 2.6 W/ (m·K) was measured.

Limestone from Rače (L=11 cm)

Shaly claystone in the village of Jesenica (L=8 cm)

Light brown siltstone in the village of Otalež (L=9 cm)

In nature, different rocks with very different thermal conductivity often alternate in quick succession. We must therefore assess the percentage of each rock within the sequence of rocks, and calculate the mean thermal conductivity down to the planned depth of catchment. Thick sequences of mixed rocks are also suitable if at least half of the rocks contained are good conductors. Example: Assuming a composition of 40 % claystone, 10 % sandy siltstone and 50 % limestone, the mean thermal conductivity is 2.4 W/(m·K).

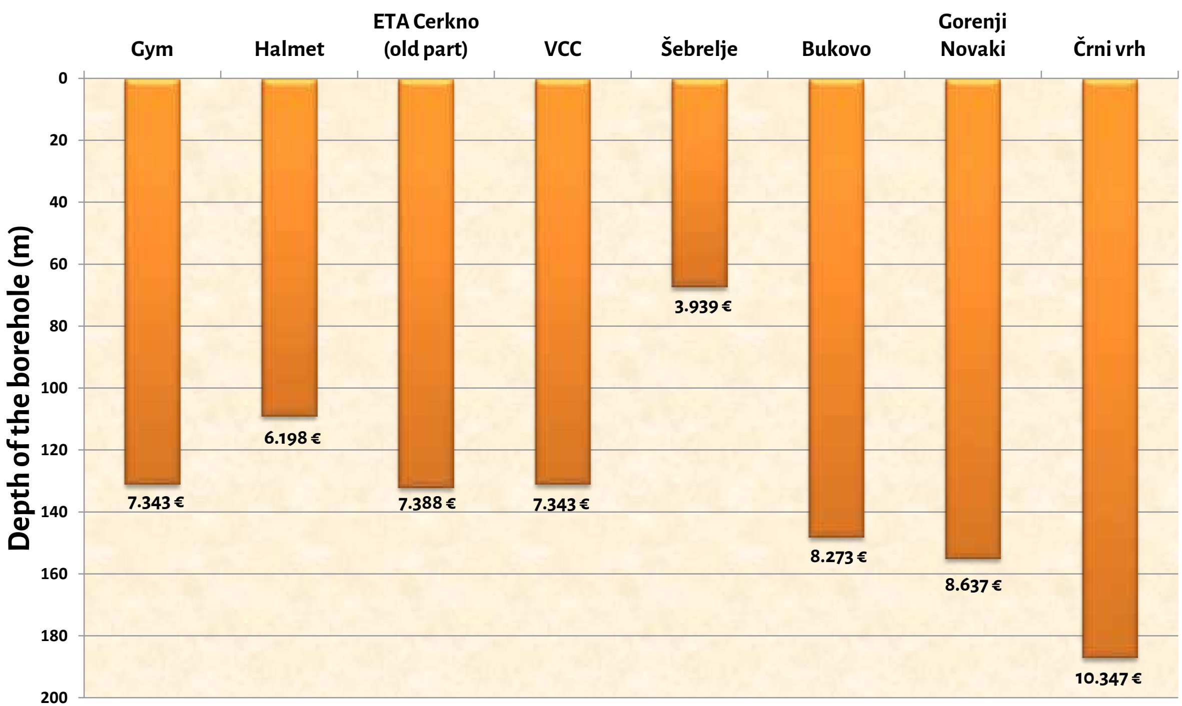


Thin-bedded claystone, siltstone and sandstone.

What is the length of the borehole heat exchangers designed for different places in the Cerkno region, and how much energy do they extract?

We must drill boreholes of various depths because, in the Cerkno region, the rocks have different thermal conductivity – and also because of other geothermal characteristics of the ground. For instance, to generate 18,300 kWh per year to heat an apartment or a house that requires about 17 m^3 of firewood or 3,000 l of heating oil, the shortest borehole heat exchangers are needed in the village of Šebrelje (67 m) and the longest on the Črni vrh mountain (187 m).

The relative comparison of different depths of boreholes needed to generate 18.300 Kwh/year for heating



Cross-section of geological layers on the crossroad at the Straža hamlet.

Geological cross-section detail on the left.

How to get to the point Na Straži?

From the starting point we drive to Glavni trg and go left and after around 4.6 km we turn left towards Idrija. After 500m we turn left on the road which takes us to the village of Straža. The point is located on the crossroad with the main and side road. Point 6 is also the starting point to reach Point 1 – Zaganjalka intermittent spring.

Crossroads at Straža

STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Straža (264 m)
DISTANCE: 5.330 m

9 min

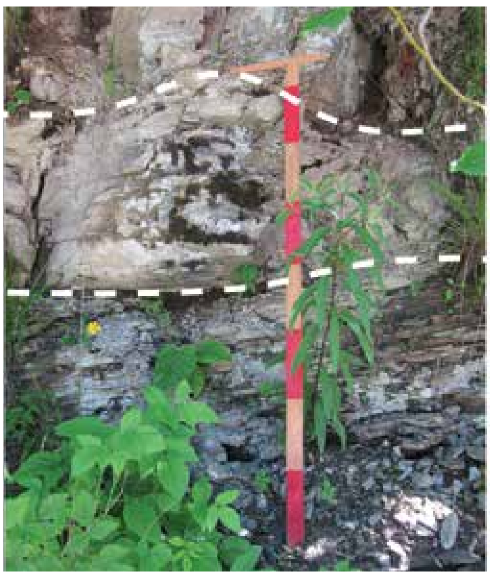
60 min

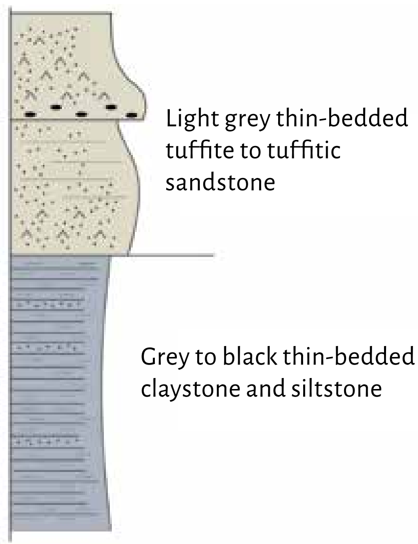
CROSS-SECTION OF THE GEOLOGICAL STRATA FORMING THE TERRITORY OF THE NORTHERN PART OF THE CERKNO REGION – ČRNI VRH MOUNTAIN

Rock diversity in the Cerkno region is the cause of diverse thermal conductivity.

At the gravel road leading from the hamlet of Gorenji Novaki to the ski slopes of the Črni vrh mountain, about 500 m before the Alpska Perla hotel, is a road cutting 15 m deep exposing Middle Triassic rocks dating back 240 million years.

Such rocks occur that are connected with intense volcanic activity. Thick strata of tuff to tuff-sandstone alternate with pockets of thin-layered dark claystone and siltstone. In the very upper part of the outcrop above the road we can observe distinct, thin laminated quartz sandstone. The layers dip at a gentle angle toward the north.





Detail from the cross-section on the left.

These rocks are rather common in the Cerkno region.

They are present in a wide area of the Črni vrh mountain, but also form extensive sections in the central, north-western and north-eastern parts of the municipality of Cerkno. The presence of volcanic rock grains and quartz grains in the tuff and quartz sandstone allows for good thermal conductivity. The conductivity measured in the tuff layers is about 3.0 W/(m·K) and in tuff sandstone 2.45 W/(m·K), while a conductivity value of up to 5.3 W/(m·K) was measured in some quartz sandstone samples. The conductivity of the claystone interlayers is significantly lower and does not exceed 1.8 W/(m·K). Around the Črni vrh mountain, these rocks contain a large number of springs whose water carries the heat of the deep-lying rocks to the surface.

Detail from the picture below.

Layers of laminated sandstone (gelogical hammer for the scale).

Tuffite in the village of Gorenji Novaki

Tuffitic sandstone from Črni vrh (L=10 cm)

Quartz sandstone from Črni vrh (L=11 cm)

Why would a borehole heat exchanger need to be deeper on the Črni vrh mountain than in Cerkno?

The rocks we can find at an altitude of 1,250 m above sea level have similar geothermal characteristics as e.g. those in the village of Cerkno, but the potential also depends heavily on the average annual ground surface temperature. The latter is obviously subject to the altitude of the area. Therefore, the average annual temperature To = 5.5 °C on the Črni vrh mountain, and To = 10 °C in the town of Cerkno. Soil temperatures fall by about 0.5 °C with each 100 m gain in altitude above sea level.

Contact between tuff and claystone – tuff above and claystone beneath

Due to the difference in the average annual soil temperature, the borehole heat exchanger on the Črni vrh mountain would need to be 45 deeper than in the town of Cerkno in order to achieve the same power output and energy extraction rate (in our case 18,300 kWh per year).

Detail from the picture on left

Detail from the picture on left

How to get to the Point on Črni Vrh mountain?

From the starting point we drive to the Glavni Trg, where we turn left and after a few meters continue into Cvetkova Cesta. We continue straight, passing through the villages of Poljane, Dolenji Novaki (Past Franja Partisan Hospital), and Gorenji Novaki until we reach the crossroad. We continue straight until we reach Počivalo (a big parking area). From there we continue along the narrow asphalt road until we reach a crossroad.

Crossroads before the Ski center Cerkno – chair lift Počivalo

Mountain hut Alpine pearl

STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Črni vrh crossroad (1.209 m)
DISTANCE: 13.800 m

30 min

40 min (Počivalo)

8 CROSS-SECTION OF GEOLOGICAL STRATA AT DEPTHS OF 95 TO 365 m BELOW HOTEL CERKNO - BRDCE

The least conductive rocks in the Cerkno region have thermal conductivity characteristics similar to concrete, while the most conductive rocks have up to four times that conductivity.

In the Brdce area, we find rocks dating from the Upper Triassic period (Carnian) that are about 230 million years old. Here, thick strata of fine-grained sandstone alternate with thin interlayers of siltstone and black shaly mudstone. The sandstone is mostly composed of up to 2 mm-thick grains of carbonate and volcanic rock as well as of quartz, and the mudstone of different clay- or silt-sized particles.

Layers of sandstone, siltstone and mudstone - Brdce

Detail from the picture on left

These rocks were penetrated at depths of 95 to 365 m by the borehole at Hotel Cerkno.

They outcrop at the surface over a wide area to the north of Cerkno, in a belt stretching from the village of Zakojca through the village of Jesenice to the villages of Gorje and Davča.

View on the geological cross-section on previous page

View on Cerkno landscape

The thermal conductivity of the rocks [λ] defines how well heat energy transfers through the material.

Based on thermal conductivity measurements on 32 rock samples from the Cerkno region, geologists were able to determine which rocks had the best characteristics for the installation of shallow geothermal systems. The rocks with the highest thermal conductivity are best suited to exploit the Earth's heat, because they enable the heat that was extracted from the shallow underground to be recharged fastest.

Results of the thermal conductivity measurements on typical rocks compared with other materials

Location	Type of rock	Age of the rock	Average thermal conductivity W/(m·K)
Črni Vrh	Siltstone and shaly claystone	Middle Triassic	1,78
Brdce	Siltstone	Late Triassic	1,95
Rače (by the stream)	Limestone	Early Triassic	2,64
Brdce	Sandstone	Late Triassic	2,75
Mlin (Pot pod Bregom)	Quartz sandstone with conglomerate	Carboniferous	3,91
Žabže	Massive crystal dolomite	Middle and Late Triassic	5,59
Thermal Conductivity of different materials	Wood		0,08
	Water		0,6
	Brick		0,8
	Cement		1,4
	Ice (0 °C)		2,18

How to get to the Point Brdce?

From the starting point we head towards Glavni Trg. From here we go down Jerebova ulica after around 30 m we turn left up the hill, following the trail to the top where we turn right and climb up a paved road to the highest point. We have to be careful not to reach the hayrack (on the right). Look for a small path on the right which brings us to the steps that lead to our destination. Continuing further to the monument a beautiful view on Cerkno opens up in front of us.

View on the point 8

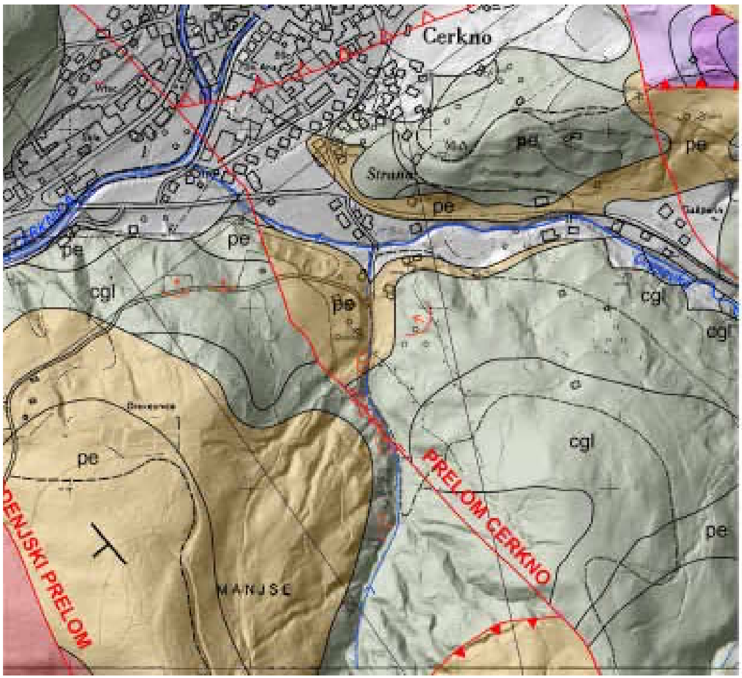
STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Brdce (330 m)
DISTANCE: 370 m

5 min

9 CROSS-SECTION OF TECTONICALLY DEFORMED OLDEST ROCKS IN THE MUNICIPALITY OF CERKNO – PADRUPA BROOK

The tectonically deformed geological layers are equally suitable for geothermal boreholes; however, it must be examined whether the area is prone to landslides.

Over a long stretch of the left bank of the Padrupa brook Carboniferous rocks can be found. At some 300 million years or more, they are the oldest rocks found in the wider Cerkno region. These are mostly alternating 1–10 cm-thin layers of quartz sandstone and dark-grey shaly claystone. The nearby rocks are characterized by strongly tectonically folded and deformed strata, impacting the borehole drilling conditions.



Geological map section showing the fault trace near the point under discussion.

Alternation of claystone and sandstone

Tectonic overthrusting has piled older rocks on top of younger rocks.

The sequence of rocks exposed at the left tributary of the Oresovka brook was drilled through, in its entire length of 134 m, by the borehole Ce-1/94 at Rajda in the Oresovka valley. The borehole Ce-2/95 penetrated these layers down to a depth of 95 m, and then further down to younger rocks. On this basis, the geological thrust structure of the territory was demonstrated (see also point 5).

Folded thin sandstone and claystone layers from the Carboniferous period.

Limitations to planning the extraction of shallow geothermal energy

If the rocks are tectonically deformed, this normally leads to a significant deterioration of its geomechanical properties; as a result, landslides are frequent under these conditions. Consequently, the stability of slopes must be considered when installing geothermal systems.

Special conditions or limitations to the exploitation of geothermal energy may also apply in protected or other special areas, such as water protection zones where spatial interventions are limited.

Padrupnca stream where the geothermal learning point with the cross section of tectonically deformed oldest rocks in the Cerkno Region.

How to get to Padrupa on the left bank of the stream Oresovka?

From the starting point we walk to Glavni trg, there we turn right and continue to the intersection with the bypass. There we turn towards Kladje. At the house Gozdarska pot 2, on the right, we continue on asphalt road for approximately 150 m, to the last house (Gozdarska pot 9). Just before the curve, we turn right on macadam road. After around 300 m we reach our destination where we can observe wrinkled thin layers of rocks on the right bank of the tributary Padrupnca.

The Padrupnca creek

STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Padrupa (425m)
DISTANCE: 1.020 m

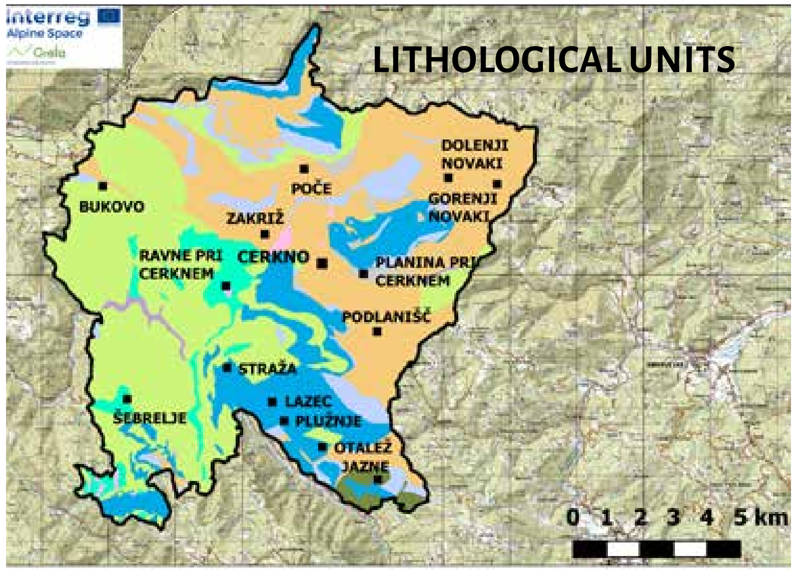
10 min

10 TERRITORY WITH THE BEST ROCK THERMAL CONDUCTIVITY IN THE CERKNO REGION – THE VILLAGE OF ŠEBRELJE

With a borehole heat exchanger 100 m deep it is possible to extract about 5 to 16 MWh of shallow geothermal energy per year from the Earth, at various places in the municipality of Cerkno. The highest natural potential for borehole heat exchangers is located in the western part of the municipality.

Based on the thermal conductivity measured in the rocks and the lithological makeup of the Cerkno region, geologists have concluded that the most favourable rocks for the exploitation of shallow geothermal heat are found on the Šebrelje plateau, which is largely formed of massive grainy dolomite dating from the Middle and Upper Triassic (about 230 million years).

Only in the upper part of the plateau – in the area covering the hamlets of Dolenja vas, Na Osredku, Na Miriših, Srednja vas and Šebrelje – bedded dolomite is found as a thin nappe over massive dolomite. Occasionally it contains chert – amorphous quartz.



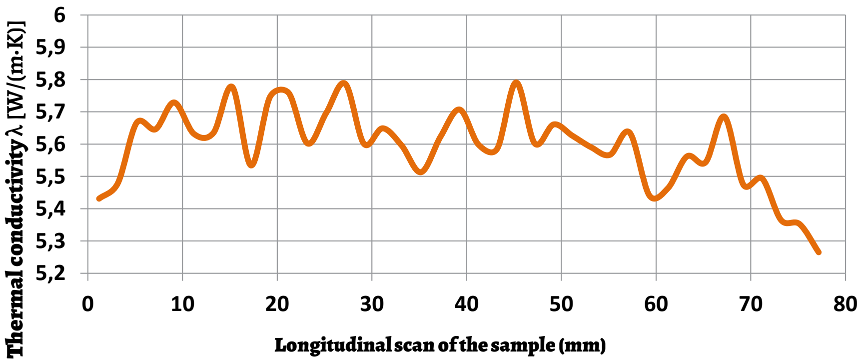
- Limestone
- Limestone alternating with clastic sedimentary rocks
- Dolomite
- Dolomite alternating with clastic sedimentary rocks
- Alteration of different grainy clastic and carbonate rock types
- Vulcanic rocks and their tuffs
- Predominantly coarse-grained volcanic rocks
- Clayey gravel - saturated with water (alluvium)
- Gravel - dry (slope sediments)

A beautiful outcrop of grainy massive dolomite can be seen on the Šebrelje plateau beneath St. Ivan's church at the entrance to a cavern dating back before World War I.

Similar rocks can be found in a wider area between the hamlets of Želin and Bukovo. Due to its crystal structure (large grains), dolomite exhibits relatively high thermal conductivity. In a dolomite sample from the hamlet of Žabže, an extremely high thermal conductivity value of 5.6 W/(m·K) was measured.

Thermal conductivity measurements taken on a sample of massive grainy dolomite - $^{1}T_3^{1}$ from the hamlet of Žabže (near Bukovo)

$\lambda_{average} = 5,6$ W/(m·K)



Massive crystalloid dolomite from Žabže (L=11 cm)

Bedded dolomite in the Srednja vas hamlet

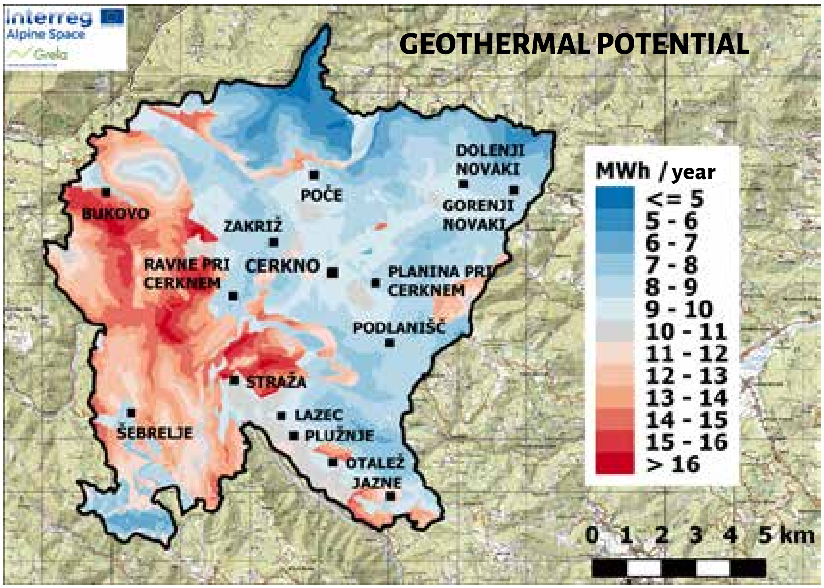
Entrance into the cavern

Fissured grained dolomite at the entrance into the cavern

Where in the municipality of Cerkno can we find the best conditions for harnessing geothermal energy?

The map shows the energy potential of a 100 m-deep borehole heat exchanger, using the G.POT method (Casasso et al., 2017). In the municipality of Cerkno, the energy potential varies significantly, and commonly ranges between 5 and 16 MWh per year. Higher values can be found in dolomite areas (similar to this site), e.g. in the hamlets of Bukovo, Orehek and Reka (14 MWh per year), Jagršče, Police and Jazne (11 MWh per year).

Map of shallow geothermal energy potential for a geothermal probe of 100 m




Dolomite rocks


View on the valley of Idrijca

If we convert the amount of energy we consume over a year for heating into megawatt hours (MWh), we can use the map to approximate the depth of the borehole needed.

For example: If we consume 2,300 l of heating oil per year for an old oil boiler with 70 % efficiency, this corresponds to 16 MWh. About one quarter of this energy is provided by a heat pump, and the remaining 12 MWh by extracting shallow geothermal energy from the borehole. In the areas shown in red, a borehole 100 m deep or less would be sufficient for that purpose. In the other areas, the borehole would accordingly need to be deeper. A relatively deep borehole can be substituted by two or more relatively shallow boreholes.

How to get to the cavern from the World War One in the village of Šebrelje?

From the starting point we drive towards Glavni Trg and turn right towards Tolmin. We continue on this road until we reach the village of Stopnik, where we turn left for Šebrelje. When we get to the centre of Šebrelje, the road signs show us the way to the church of St. Ivan. A narrow macadam road brings us to the church where we can park. Continuing on foot we turn right just before reaching the church and follow the trail to the entrance of the cavern.

STARTING POINT: Hotel Cerkno (321 m)
DESTINATION: Church of St. Ivan in Šebrelje (552 m)
DISTANCE: 18.300 m

35 min

LOCATION POINTS OF GEOTHERMAL EDUCATIONAL TRAIL

2 ECO-ENERGY PARK WITH LOG CABIN DISPLAYING RENEWABLE ENERGY SOURCES AT THE PRIMARY SCHOOL

3 GEOTHERMAL BOREHOLE Ce-1/94 – AT RAJDA

4 BOREHOLE HEAT EXCHANGER FIELD AT THE MULTI-PURPOSE CENTER OF CERKNO

5 DEEP GEOTHERMAL BOREHOLE Ce-2/95 AT HOTEL CERKNO

8 CROSS-SECTION OF GEOLOGICAL STRATA AT DEPTHS OF 95 TO 365 BELOW HOTEL CERKNO – BRDCE

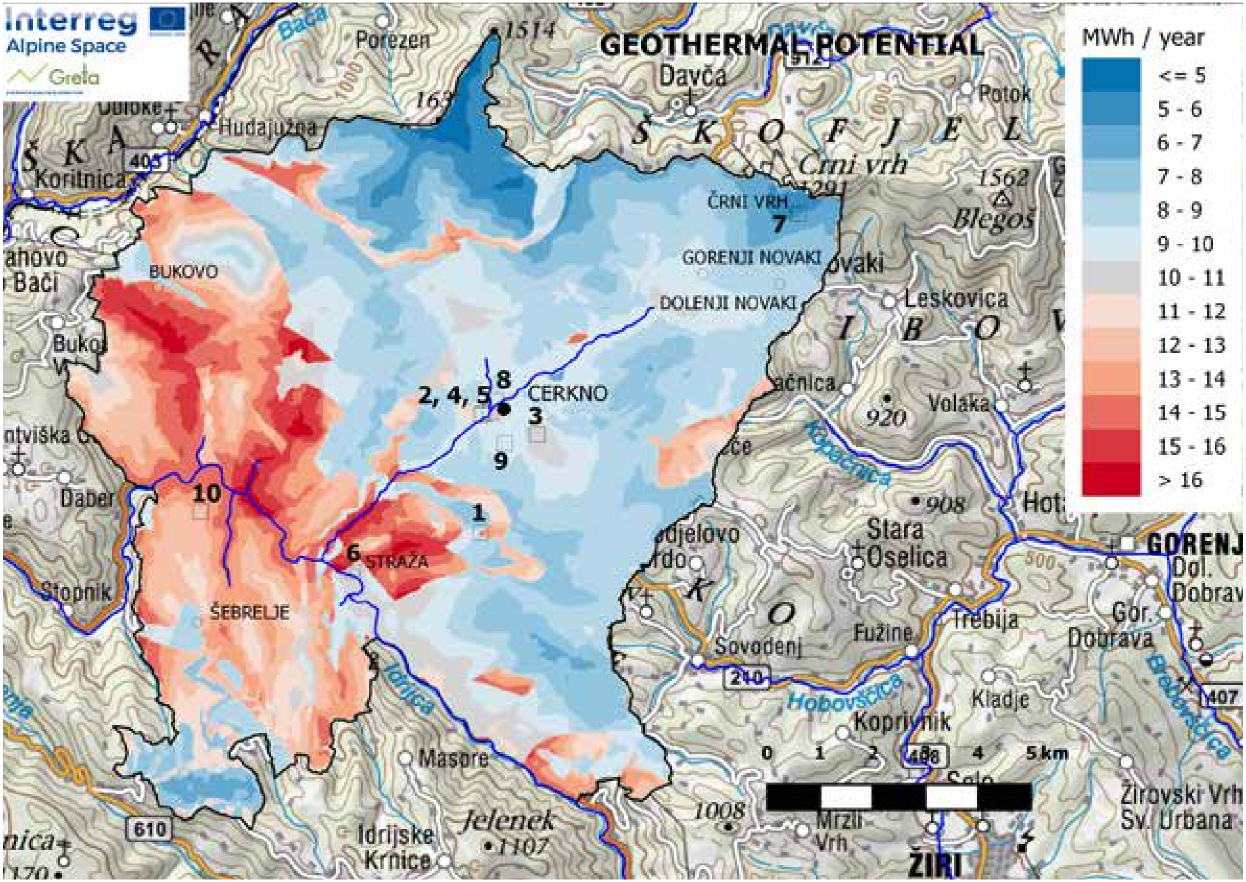
9 CROSS-SECTION OF TECTONICALLY DEFORMED OLDEST ROCKS IN THE MUNICIPALITY OF CERKNO – PADRUPA BROOK

1 INTERMITTENT SPRING OF ZAGANJALKA NEAR STRAŽA

6 CROSS - SECTION OF GEOLOGICAL STRATA THAT FORM THE TERRITORY OF THE CENTRAL AND SOUTHERN PART OF THE CERKNO REGION – THE HAMLET OF STRAŽA

7 CROSS-SECTION OF THE GEOLOGICAL STRATA FORMING THE TERRITORY OF THE NOTHERN PART OF THE CERKNO REGION – ČRNI VRH MOUNTAIN

10 TERRITORY WITH THE BEST ROCK THERMAL CONDUCTIVITY IN THE CERKNO REGION – THE VILLAGE OF ŠEBRELJE



Geothermal trail leading us from lower geothermal potential (blue) to the higher (red). By being observant while strolling the 10 geothermal points, one can recognize many specificities of Shallow geothermal energy and its possibilities of exploitation.

COLOPHONE

1. INTERMITTENT SPRING OF ZAGANJALKA NEAR STRAŽA
   Chart 1: Measurements of water eruptions (Podobnik, R. 1968: Zaganjalka. Idrijski razgledi 13-3, 64–67. Idrija.).
   Figure 1: Water-to-water system (BRGM, GRETA-33, 2018). Graph2: Well capacity (S. Pestotnik). Photo: B. Tavčar.
2. ECO-ENERGY PARK WITH LOG CABIN DISPLAYING RENEWABLE ENERGY SOURCES AT THE PRIMARY SCHOOL
   Chart 1: Temperature flow (D. Rajver, S. Pestotnik). Photo: B. Tavčar, J. Prestor.
3. GEOTHERMAL BOREHOLE Ce-1/94 – AT RAJDA
   Photo: Panoramic view (J. Jež). Sketch: Heat exchangers. (BRGM, GRETA-37, 2018). Photo: B. Tavčar.
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   Figure 1: Temperature field (J. Prestor, S. Pestotnik). Photo: B. Tavčar.
5. DEEP GEOTHERMAL BOREHOLE Ce-2/95 AT HOTEL CERKNO
   Chart 1: Measured temperatures (D. Rajver). Figure1: Profile (adapted after Placer, 2000. J. Jež, K. Koren). Photo: B.Tavčar, P. Jovanović.
6. CROSS -SECTION OF GEOLOGICAL STRATA THAT FORM THE TERRITORY OF THE CENTRAL AND SOUTHERN PART OF THE CERKNO REGION – THE HAMLET OF STRAŽA Figure1: Layers (J. Jež). Chart 1: Comparison of borehole depths needed for the supply of annual energy needs (J Prestor, J. Svetina). Photo: T. Prestor (rocks); B. Tavčar.
7. CROSS-SECTION OF THE GEOLOGICAL STRATA FORMING THE TERRITORY OF THE NOTHERN PART OF THE CERKNO REGION – ČRNI VRH MOUNTAIN Figure1: Layers (J. Jež). Photo: T. Prestor (rocks), B. Tavčar.
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9. CROSS-SECTION OF TECTONICALLY DEFORMED OLDEST ROCKS IN THE MUNICIPALITY OF CERKNO – PADRUPA BROOK
   Figure1: Layers with the geological map (J. Jež). Photo: J. Jež (folded thin layers), B. Tavčar.
10. TERRITORY WITH THE BEST ROCK THERMAL CONDUCTIVITY IN THE CERKNO REGION – THE VILLAGE OF ŠEBRELJE
    Map1: Lithological (Report- Geological models of Cerkno for the assessment of shallow geothermal energy potential (Project GRETA), GeoZS, 2018). Graph1: Sample measurements (D. Rajver). Map 4: Geological models of Cerkno for the assessment of shallow geothermal energy potential (Project GRETA), GeoZS, 2018). Photo: T. Prestor (rock), B. Tavčar.

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GEOLOGICAL VARIETY OF CERKNO REGION

- *Cerkno has a rich tradition of exploiting geothermal energy for heating purposes, and built the first geothermal educational trail in Slovenia.*
- *The municipality of Cerkno boasts one of the most diverse geological settings in Slovenia.*
- *The deepest operating geothermal borehole in the western part of Slovenia, designated as Ce-2/95, is located at Hotel Cerkno.*
- *The multi-purpose center of Cerkno is located in an older building that is heated and cooled by means of shallow geothermal energy extracted via a field of 12 borehole heat exchangers with a depth of 100 metres.*
- *The primary school and the multi-purpose center of Cerkno are public buildings whose heating systems rely on a combination of biomass and shallow geothermal energy.*
- *The primary school of Cerkno features an ecological chalet that shows the ways different sources of renewable energy are used, including shallow geothermal energy.*
- *The area of the municipality of Cerkno is rich in water resources and springs.*
- *The intermittent spring (also: rhythmic spring) close to the village of Straža pri Cerknem is one of the rare springs whose flow of water is subject to rhythmic fluctuations as a result of the special hydraulic conditions there.*

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