p-ISSN 2460-0768 e-ISSN 2597-6044 *GeoEco, Vol. 10, No 2. July 2024 Page. 205-220*
https://doi.org/10.20961/ge.v10i2.86131 https://jurnal.uns.ac.id/GeoEco/article/view/86131

TOPOGRAPHIC MAPPING, TEMPERATURE DISTRIBUTION, AND pH OF HOT SPRINGS IN PADANG GANTING, TANAH DATAR, WEST SUMATRA: A PRELIMINARY STUDY

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ARTICLE INFO

Article History
Received : 22/04/24
Revised : 28/05/24
Accepted : 26/06/24

Citation:
Algifari, A., Ardiansyah, W., and Ramadhan, I.G, (2024) Topographic Mapping, Temperature Distribution, and pH of Hot Springs in Padang Ganting, Tanah Datar, West Sumatra: A Preliminary Study. GeoEco. Vol. 10, No. 2.

ABSTRACT

This preliminary study explores the hot springs in Padang Ganting, Tanah Datar, West Sumatra, at coordinates 00°34'8.404" S - 100°42'45.716" E and 0°31'26.431" S - 100°45'27.598" E. The research was conducted using geological and geochemical methods in the geothermal field. The collected data includes coordinates of the area, temperature, and pH of the hot springs. The results show a pH distribution ranges from 6 to 7 at several points of the hot springs, with slightly brackish characteristics, and the temperature of the hot springs ranges from 41°C to 51°C. The immature meteoric hot springs originate from the granite formation, indicating the possibility of magma intrusion to the surface, possibly caused by the oroclinal shear segment in the upper part of the Ombilin basin. This study provides a basis for further geological investigations into the geothermal potential and prospects for further development in the geothermal field, contributing to understanding the geological processes in the region.

Keywords: *Hot Spring Geochemistry; Padang Ganting; pH Geothermal; Temperature.*

INTRODUCTION

Padang Ganting, located in Tanah Datar, West Sumatra, has hot springs that attract tourists and is currently one of the tourist attractions registered under the Department of Tourism, Youth, and Sports of Tanah Datar Regency (Amsar, 2023). The hot spring tourism in this area is intriguing to explore as it reflects complex geological processes and its potential for geothermal energy. Geothermal geological studies are interesting to understand the origins and formation processes of the hot springs. In this context, topographic mapping, temperature distribution, and pH levels of the hot springs in Padang Ganting are initial investigative steps by researchers. Topographic mapping is necessary to understand the geological conditions around the Padang Ganting hot springs area, while the temperature distribution and pH levels provide insights into the geochemical characteristics of the geothermal features and the surrounding environmental conditions. This information forms the basis for developing sustainable management strategies for the hot spring resources and harnessing the geothermal potential.

Through detailed mapping and analysis supported by additional information, it is hoped that the available geothermal resources in Padang Ganting can be revealed. This research not only provides insights into the geological conditions involved in the formation of the hot springs but also opens up opportunities for the development of supporting infrastructure in the area. Thus, this study is an important initial step in understanding and harnessing the geothermal potential in Padang Ganting, Tanah Datar, West Sumatra.

Hot springs are part of the geothermal system or Earth's heat. Geothermal energy found in volcanic zones refers to the phenomenon of heat energy generated from geothermal activity associated with magmatic systems in active volcanic crusts. This process involves heat produced from the formation of magma beneath the Earth's surface, which heats water in geothermal reservoirs located near these volcanic zones (Marry, 2017). Hot springs form when surface water infiltrates into the Earth's crust and reaches layers near magma or hot rocks beneath the surface. This process heats the water, which then rises back to the surface through cracks or fissures in the Earth's crust. (Umar et al., 2020). After reaching the surface, this hot water then forms hot springs that can be used by humans for various purposes, such as bathing or as a source of thermal energy. These hot springs are natural outlets where the heated water emerges from the ground, often enriched with minerals, and they are sought after for their therapeutic and recreational benefits. Additionally, in geothermal areas, the heat energy contained in hot springs can be harnessed through technologies like geothermal power plants to generate electricity or provide heating for buildings. Therefore, hot springs serve practical and recreational functions, contributing to local economies, and enhancing wellness experiences for visitors.

MATERIALS AND METHODS

The research methodology employed in this study involves the application of field methods in mapping for geological and geochemical exploration (Idrus, 2021). Mapping studies of hot spring areas differ significantly from related research, such as that conducted by Zamani & Iemaaniah (Zamani & Iemaaniah, 2024) on epikarst hydrogeology in Donorojo, Pacitan, East Java, which utilized geological maps and assisted by Geographic Information System (GIS) tools. However, this study includes GIS-assisted mapping information, similar to research by Ferdi, Saputra, Rahmawati, & Budianta (Ferdi, Saputra, Rahmawati, & Budianta, 2022) in their mapping of land and flood-prone areas in Tolitoli Regency, Central Sulawesi.

District Accessibility

The hot spring is located in Koto Gadang Village, Hilir, Padang Ganting Subdistrict, Tanah Datar Regency, West Sumatra with at coordinates 00°34'8.404" S - 100°42'45.716" E and 0°31'26.431" S - 100°45'27.598" E. Padang Ganting boasts a captivating hot spring tourist attraction. Situated in the northeastern part of Padang, West Sumatra, this destination offers a serene escape for visitors seeking relaxation and rejuvenation amidst natural surroundings. Accessible via land routes from Universitas Negeri Padang, travelers can embark on a scenic journey of approximately 111 kilometers through Padang Panjang or opt for an alternative route spanning 118 kilometers via Solok. The allure of Padang Ganting lies in its natural hot springs, which bubble forth from the earth's depths, providing therapeutic benefits and a soothing environment for visitors. Its strategic location makes it easily reachable by road, bordered by Tanjung Emas to the north and west, while X Koto di Ateh in Solok lies to its west. To the east, Padang Ganting shares its boundary with Lintau. To the south, it is neighbored by Talawi or 40 km northwest of Sawahlunto (Koesoemadinata, 1981). The location maps in **Figure 2** and **Figure 3** indicate specific areas in Padang Ganting, Tanah Datar, West Sumatra, where the exploration of hot springs is conducted.

Tools and Materials

The tools and materials used in this study are categorized based on primary and secondary data sources, as depicted in **Table 1.**

Table 1. Equipment and Research Materials

Category	Equipment/ Material	Data Source
Primary Data	GPS devices, measuring tape, thermometer, pH meter, geological hammer, sample bags	Field measurements
Secondary Data	Geological maps, previous research papers, reference books, Surfer software	Literature review, data processing tools

Research Procedure

The research begins by determining coordinate points, where several coordinates around the hot spring source are identified and recorded using GPS devices. Accurate placement ensures comprehensive area coverage. Subsequently, field measurements are conducted by directly measuring the hot water temperature at the spring source using a thermometer and assessing the pH level using pH indicators. All measurements are systematically recorded for consistency and accuracy.

The next stage involves collecting rock samples from various points around the hot spring area. These samples are stored for further analysis, and the types of rocks are identified to support the study of hydrothermal mineralization. Tracking activities are carried out at each identified point, with coordinates recorded using GPS. If additional hot spring sources are found, temperature and pH measurements are repeated, and rock samples are collected with their coordinates noted. Tracking activities are concluded by closing the tracking points on the GPS, ensuring all coordinates are accurately logged.

The final stage comprises mapping and data analysis using Surfer software to map topographic features, temperature distribution, and pH distribution. The collected data is analyzed to gain insights into the characteristics of the geothermal area. Research flow diagram show in **Figure 1**.

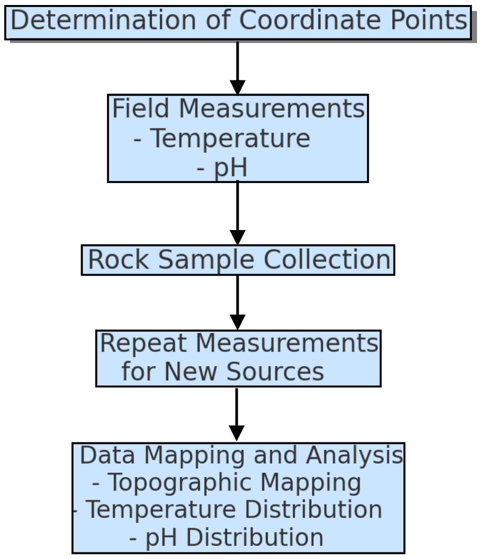

Figure 1. Research flow diagram

Comprehensive Data Analysis

This methodology provides a detailed framework for collecting and analyzing data on the phenomenon of hot springs in Padang Ganting, Tanah Datar, West Sumatra. The systematic approach ensures that all relevant geological and geochemical information is gathered and interpreted accurately, contributing to a deeper understanding of the geothermal potential in this region.

RESULTS AND DISCUSSION

Earth science studies in the Padang Ganting area have covered several important research aspects, such as the geomorphological study by (Adelin Aviva, 2022), which provides an understanding of the surface forms and geomorphic processes in the region, and the study of the geochemical characteristics of hot springs by (Fajrin & Putra, 2021), which identified the chemical composition and physical properties of the hot springs. However, there has not been any specific research focused on topographic mapping as well as the distribution of temperature and pH in the hot spring area of Padang Ganting. Therefore, this study will focus more on the aspects of mapping, physics, and geochemistry of the hot spring sources in Padang Ganting to complement the comprehensive understanding of geothermal condition in the area.

Geological Conditions

The geological conditions at the Padang Ganting hot springs, as described by (Adelin Aviva, 2022), reveal a morphological landscape characterized by high hills with elevations ranging from 500 to 925 meter above sea level. These hills exhibit steep slopes and valleys, indicative of intense erosion processes shaping the terrain. The denudational hills consist of lithologies that have undergone weathering, comprising sandstone, shale, clay, and granite formations. This geological composition suggests a history of sedimentation and subsequent erosion, contributing to the diverse topography and rock formations observed in the area. Understanding the geological morphology of the Padang Ganting hot springs provides valuable insights into the landscape's formation processes and the underlying geological condition that influence its hydrological features and environmental characteristics. Geological map of Padang Ganting as seen on **Figure 4.**

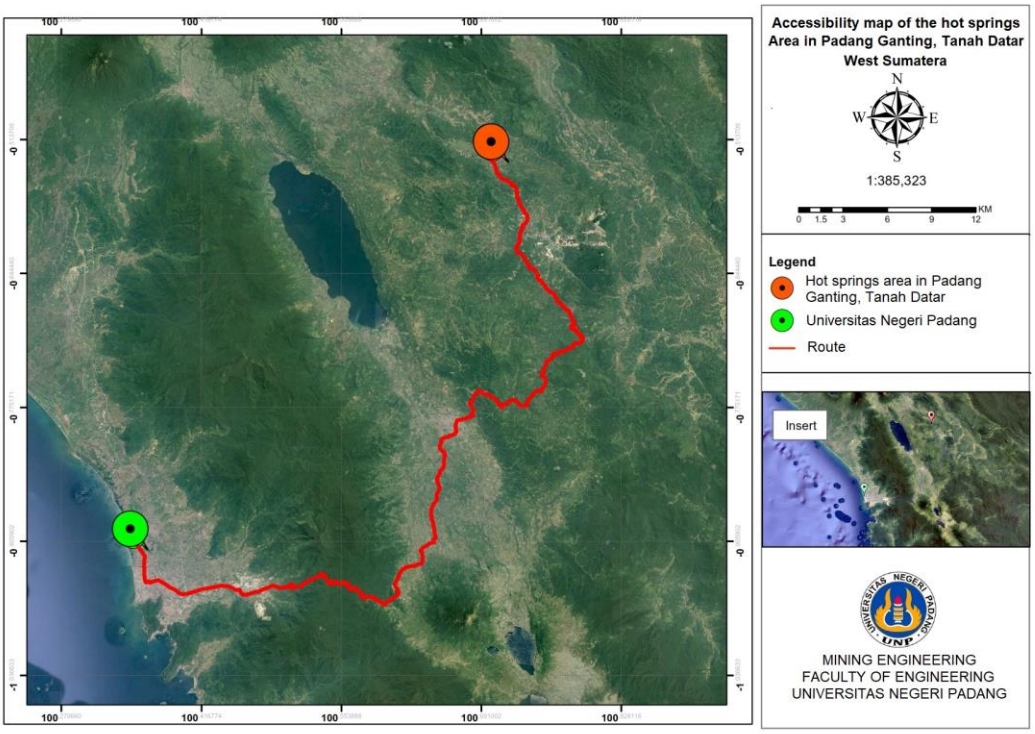

Figure 2. The Google map of the hot spring area of Padang Ganting
(Source: map processing from www.map.google.com)

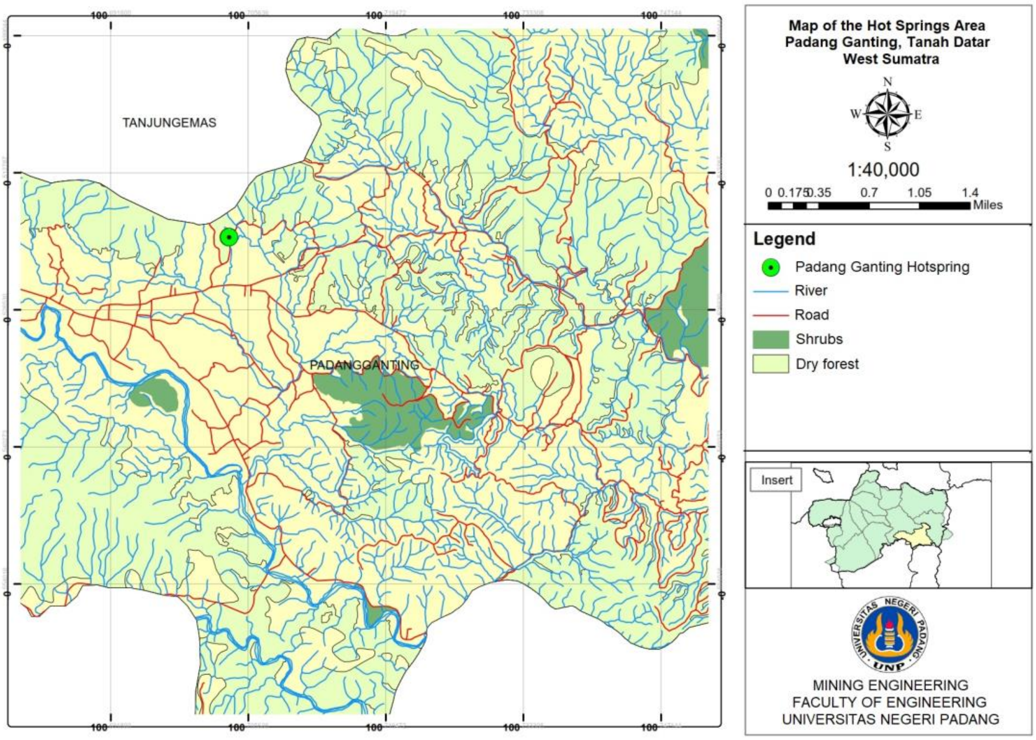

Figure 3. The Google map of Padang Ganting Region
(Source: map processing from www.map.google.com)

This area is located in a predominantly hilly region with geological structures of uplift faults and fractures, and the morphological characteristics of the Batang Selo and Batang Ombilin river basins. The main rock formation that comprises the Padang Ganting area is the granite formation. Fault structures enable hot water fluids to emerge to the surface, similar to the phenomenon observed in the Bojong geothermal environment in Tegal, Central Java. (Wahyudi, 2021). This granite formation is formed as a result of the expansion of magma that rises to the surface due to the presence of oroclinal strike-slip faults at the top of the Ombilin basin. It becomes a phenomenon that goes hand in hand between faults and magma intrusion (Fashihullisan, Susilo, & Jam'an, 2014). The process of magma expansion was shaping the geological and geothermal characteristics of the area. In addition to the granite formation, there are also the Sangkarewang Formation and the Brani Formation. Both of these formations have Miocene ages during the Tertiary period and serve as sediment fillings in the Ombilin basin (Algifari, Yanti, & Nauli, 2023). These sediments add complexity to the geology of the area, with a combination of granite formations resulting from magma expansion and the sediment fillings of the Ombilin basin in the form of the Sangkarewang and Brani Formations.

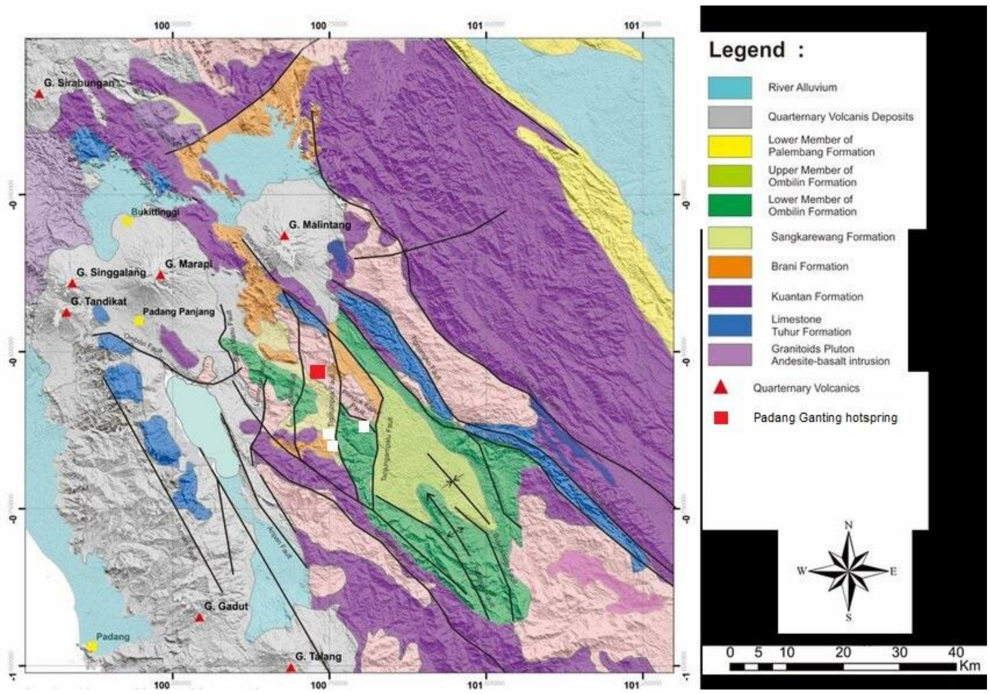

Figure 4. Geological map of Padang Ganting
(Modified from (Aulia Agus Patria and Ferian Anggara, 2022))

p-ISSN 2460-0768 e-ISSN 2597-6044
https://doi.org/10.20961/ge.v10i2.86131

Topography of the Hot Spring Environment

The process of collecting topographic data begins with the preparation of necessary equipment, including GPS, rangefinders, compasses, and maps of the area to be mapped. Subsequently, representative and diverse measurement locations are selected in the target area. Measurement points are chosen considering various topographic features such as hilltops, valleys, and other significant elevation changes (see **Figure 5**). At each point, coordinates are measured using GPS, ensuring that the device is synchronized with satellites for high accuracy (see **Figure 6**.). The coordinates of each point are meticulously recorded. Next, elevation measurements are taken using a rangefinder to measure the vertical distance between the measurement point and a reference point, such as the sea level or a fixed point with a known elevation. The recorded data are then analyzed and input into Surfer mapping software. In this data collection process, the hot spring area on the west side is identified as hilly, with hot spring points located adjacent to these hills extending into lower areas. This information provides a better understanding of the land structure and morphology around the hot springs. By utilizing the obtained topographic data and Surfer software, we can visualize more clearly how the landforms relate to the distribution of hot springs. The topographic survey results at elevations of 270-322 meters above sea level indicate hilly terrain to the west and agricultural fields in the central to eastern areas. The hills to the west have undulating contours with moderate to steep slopes.

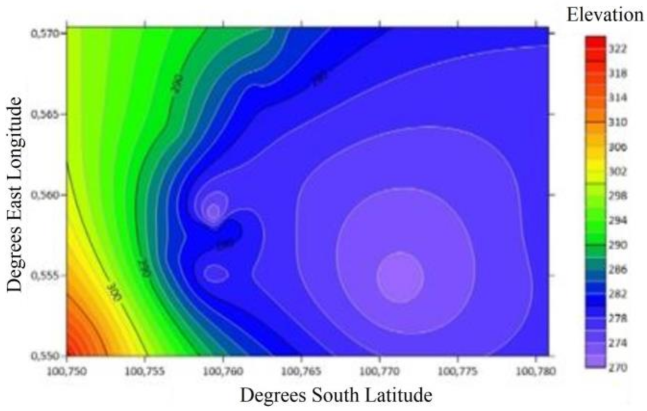

Figure 5. Topographic Map of the Padang Ganting Hot Spring area
(Source: coordinate data processing using Surfer application)

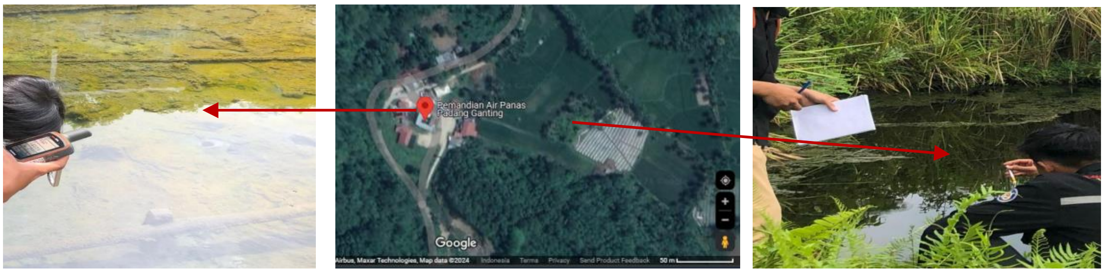

Figure 6. Padang Ganting Hot Spring Points
(Source: researcher documentation and map processing from www.map.google.com)

Distribution of Surface Hot Spring Temperature

The temperature measurement process using a rod thermometer for the hot spring is carried out with simple yet careful steps. Firstly, the rod thermometer is carefully inserted into the surface hot water, ensuring it is fully submerged and the tip reaches the deepest layer of water. Then, let the thermometer sit in the water for a few moments to ensure the temperature stabilizes and is accurately read. During the measurement, it is important to observe the thermometer's position to avoid disturbance from water flow or any other external interference that may affect the measurement results. Once the temperature stabilizes, read and record the number displayed on the thermometer scale accurately. In the case of measuring the temperature of the Padang Ganting hot springs, which range from 41-51°C, this process ensures accuracy similar to the measurement of low surface hot spring temperatures ranging from 45-57°C (Umar et al., 2020). This indicates that the temperature of the hot water falls within a range suitable for being a source of hot spring tourism attraction. Estimated distribution of hot spring temperatures in Padang Ganting shown in **Figure 7**.

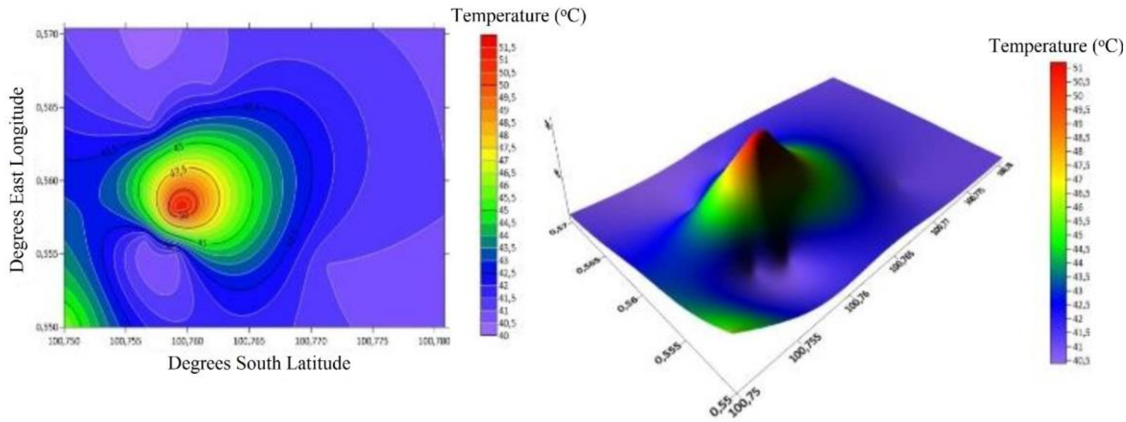

Figure 7. Estimated distribution of hot spring temperatures in Padang Ganting (Source: processing of hot spring water surface temperature data using Surfer application)

This temperature range reflects a comfortable temperature for visitors to soak in and enjoy the health benefits of natural hot springs without the risk of being too hot or too cold. With measurement results meeting these criteria, it can be ensured that the hot springs in Padang Ganting have great potential to be developed as an attractive hot spring tourism destination for tourists. Additionally, this information can serve as a basis for the development of facilities and services that cater to the needs of visitors, as well as for the promotion and marketing of the tourism destination.

Distribution of Surface Hot Spring pH

pH measurements at two hot spring water points are conducted using a pH indicator as the indicator. Firstly, the pH indicator is immersed into the hot spring water carefully, ensuring that the pH indicator is fully submerged and left immersed for a sufficient time to ensure a stable chemical reaction. Then, the pH indicator is examined to observe the color changes that occur. The range of colors displayed on the pH indicator will indicate the pH of the water, which can be compared to a standard color scale to determine the exact pH. In this case, the pH range obtained is 6-7. In addition to pH measurements, the taste of the hot water is also observed. By detecting that the hot water has a slightly brackish taste, this can provide additional indication of the chemical composition of the hot spring water. The combination of pH measurements and the slightly brackish taste of the hot water indicates the presence of certain ions in the hot water that give it its characteristic conductivity (Umar et al., 2020). Estimated Distribution of Temperature of Padang Ganting Hot Springs shown in **Figure 8.**

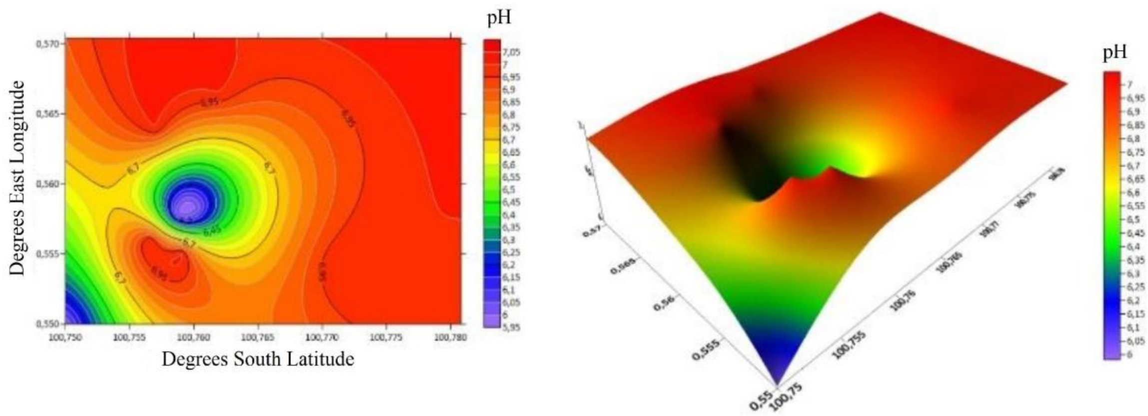

Figure 8. Estimated Distribution of Temperature of Padang Ganting Hot Springs (Source: processing of hot spring water pH data using Surfer application)

Thus, the pH measurements and observations of the taste of the hot spring water provide valuable information about the quality of the hot springs at the two points. The pH range of 6-7 falls within the water quality standards set by PERMENKES 492/MENKES/PER/IV /2010 and PP RI Number 82 (Naslilmuna, Muryani, & Santoso, 2018). The pH characteristics indicate that the hot water is mildly acidic to neutral. The slightly brackish taste of the hot water suggests the presence of minerals that contribute to its properties. This information is valuable for managing and marketing hot spring tourist attractions, as well as understanding the health benefits associated with these hot springs.

Discussion

The underground hydrological system is considered complex because groundwater interacts intensively with the surrounding rock environment it traverses (Noviani, 2021). Similarly, in hot spring areas, there is often a complex interaction between infiltrating water and geothermal heat. Rainwater or surface water seeps into the ground and moves through cracks and pores in the rocks. As it travels downwards, this water heats up due to geothermal activity in the Earth's crust. This heating process may involve direct contact with hot rocks or interaction with magma beneath the surface.

The composition of hot spring fluids is heavily influenced by their journey through the underground hydrological system. During this journey, hot water dissolves various minerals from the rocks it passes through, altering its chemical composition. These minerals may include silica, calcium, sodium, potassium, and various other metal ions that determine the geochemical characteristics of the hot spring water. Processes such as degassing, mixing with cold groundwater, and chemical reactions also affect the fluid composition.

Therefore, the intensive development of the underground hydrological system allows for deeper interaction between water and rocks, as well as more efficient heating processes, ultimately resulting in hot water with distinctive fluid compositions. Studies on topography, temperature distribution, and pH in the Padang Ganting hot spring area can provide further insights into how this underground hydrological system functions and influences the properties of the hot spring water.

The environmental mineralization zone of the hot spring area, characterized by the presence of dominant quartz-rich granite rocks, indicating significant geothermal and mineralization potential in the area. The same phenomenon occurs in the geothermal system of Langkawi Island, West Malaysia, due to the intrusion of granite, which acts as a heating source for the hydrological system (Baioumy, Nawawi, Nordin, Wagner, & Arifin, 2013). Quartz-rich granite is an indicator of complex geological processes occurring beneath the Earth's surface, often associated with hydrothermal conditions. Granites in hydrothermal environments undergo albitization due to the circulation of immature meteoric water (Shah, Sircar, Shah, & Dholakia, 2021)(Fajrin & Putra, 2021) containing alkali and alkali earth ions such as Na, K, and Ca (Kaur et al., 2012). The presence of sandstone tuff ejected by hot springs indicates the deposition of minerals from hot water solutions upon cooling. Sand tuff is composed of fragments from igneous rocks (Al Dwairi & Sharadqah, 2014). Its presence signifies significant hydrothermal activity and may hint at abundant mineralization. The high temperature distribution around the mineralization zone suggests strong geothermal potential, a characteristic feature of hydrothermal environments and a primary indicator of subsurface geothermal energy sources. The combination of high temperature and dominant quartz-rich granite indicates a potential geothermal system. The slightly brackish pH of the hot water indicates the presence of certain minerals that impart such characteristics. The near-neutral pH can result from dissolved minerals like alkali and alkali earth metals present in the hot water. The slightly brackish taste of the hot water suggests the presence of minerals such as salts, as evidenced by the content of Li, Na, K, Mg, Cl, and B in parts per million according to research conducted by (Fajrin & Putra, 2021), The alkali and alkaline earth metal content is related to the alteration products of hydrothermal environments in granitic rocks, as evidenced in geochemical studies of Central Japan (Nishimoto & Yoshida, 2010). Overall, the environmental mineralization zone with dominant quartz-rich granite, sandstone tuff deposits, high temperature distribution, and the relationship between pH and the taste of the hot water provide strong indications of significant geothermal and mineralization potential in the area. This information serves as a basis for further exploration of geothermal and mineral resources in the region, as well as for the sustainable development of hot spring tourist attractions.

CONCLUSIONS

Based on the discussed article, it can be concluded that mapping activities at hot spring environment in Padang Ganting, Tanah Datar, West Sumatra, holds significant geothermal and mineralization potential. Characteristics such as the presence of dominant quartz-rich granite rocks, low temperature distribution, and sandstone tuff deposits indicate strong geothermal potential in the area. Additionally, the environment also exhibits significant mineralization, as evidenced by the presence of quartz-rich granite rocks and sandstone tuff deposits. The hot water in Padang Ganting has a near-neutral pH and a slightly brackish taste, indicating the presence of certain minerals in the hot water. With its unique geological and geothermal characteristics, Padang Ganting has the potential to be developed into an attractive hot spring tourist destination. Furthermore, the existing geothermal and mineralization resources in the area could also serve as a significant source of economic revenue. Therefore, appropriate conservation and management measures are necessary to ensure sustainable utilization and positive impacts on the local community and the environment. As a suggestion, further research is needed to better understand the geothermal and mineralization potential in Padang Ganting. Additionally, the development of eco-friendly tourism infrastructure and facilities, as well as the importance of environmental preservation around the hot springs, should be emphasized to support the development of sustainable tourist attractions.

ACKNOWLEDGMENTS

The author would like to express gratitude to the Department of Mining Engineering at Universitas Negeri Padang for providing the opportunity to conduct a field visit to the geothermal field as part of the Geothermal Exploration and Evaluation course.

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