Analysis of the Effectiveness of Engineering Geophysical Exploration in Investigating Faults in Hot Spring Areas

The geological tectonics of hot spring area are usually complex and low depth, when using the high precision engineering geophysics technology to investigate geological tectonics in hot spring area, we can get good effects. This paper mainly introduces the geological investigation example in the hot spring fault belt , the purpose is to find out the distributions of the fault belt and the groundwater using the complex resistivity and shallow seismic technology.

In urban construction, engineering geophysics is an efficient, economical, and reliable geological exploration method. It primarily utilizes geophysical methods, focusing on shallow and ultra-shallow geological bodies. Currently, it is mainly applied to railways, bridges, airports, coastal engineering, karst, tunnels, high-rise buildings, and other areas. The main engineering geophysics methods include shallow seismic exploration, electrical methods, geological radar, gravity, magnetism, etc. Among them, shallow seismic methods also encompass seismic imaging, seismic refraction method, reflection method, and surface wave exploration, etc. Springs with abundant water often bring significant economic contributions to local economies. However, with the intensification of urbanization, the infiltration, runoff, and discharge systems of groundwater have been damaged, leading to many springs disappearing on the surface. To enhance the rational development of spring resources, it is necessary to use engineering geophysics methods to thoroughly investigate the geological structure and groundwater distribution in the spring areas.

Formaldehyde is a colorless gas with a pungent odor and is soluble in water. Due to the fact that gaseous or liquid formaldehyde easily polymerizes at room temperature and pressure, the commonly sold product is a 35%-40%

aqueous solution, known as formalin. Because the formaldehyde molecule has a carbon group, and there are two hydrogen atoms attached to the carbon group, it is highly reactive. It can undergo carbon addition, oxidation, reduction, and polymerization reactions. Hence, formaldehyde is an essential raw material in organic synthesis. Formaldehyde is harmful to humans, mainly because it can bind with proteins in the human body, altering their internal structure and causing them to coagulate. This property of formaldehyde is also often utilized for its disinfectant and preservative abilities. Formaldehyde vapor can irritate the respiratory system and severely affect the eyes. Prolonged exposure can lead to headaches, weakness, sensory disturbances, irregular sweating, temperature changes, increased pulse rate, dermatitis, edema, inflammation, and pain. When formaldehyde comes in contact with the skin, it can cause the skin to harden and even lead to localized tissue necrosis, resulting in cracks at the contact site and potential tumor formation. Formaldehyde is cytotoxic, can be absorbed through the respiratory system, digestive system, and skin, has a potent irritant effect on the skin, can cause protein coagulation necrosis in tissues, and inhibits the central nervous system. Animal experiments have shown that formaldehyde is a lung carcinogen. Indoor concentrations reaching 30mg per cubic meter can be instantly lethal. Therefore, the development of a new generation of environmentally friendly decorative materials, achieving eco-friendly and green decoration, has been put on the agenda. An effective method to control formaldehyde pollution is to close doors and windows and fumigate with ammonia water for several hours at a room temperature of 27°C.

The primary sources of formaldehyde in textiles are the free formaldehyde in auxiliaries and the formaldehyde produced by the decomposition of auxiliaries. This is mainly because the reaction in the synthesis of auxiliaries cannot be entirely complete, so the presence of free formaldehyde in the auxiliaries is inevitable. This formaldehyde is adsorbed on the surface of the fabric. Studies by the American Textile and Clothing Association have found that the amount of formaldehyde that can be adsorbed on fabric is very high. On the other hand, during the finishing process, some auxiliaries can react on the fabric to produce and release formaldehyde, or under the effects of sunlight, sweat, and body temperature, formaldehyde can be easily released from the fabric (especially in areas where the skin contacts clothing more, such as the underarms and other areas prone to sweating and friction). Similarly, certain measures can be taken to reduce or eliminate the release of formaldehyde from clothing. First, by using dyeing and printing auxiliaries that are formaldehyde-free or have ultra-low formaldehyde content. Second, by not using printing and dyeing auxiliaries that release formaldehyde during the finishing process or that release formaldehyde under the effects of sunlight, sweat, and body temperature. Volatile organic compounds (VOCs), like formaldehyde, which pollute the environment and are toxic to humans, have widespread industrial applications. However, their destructive potential cannot be overlooked. Firstly, there's a strong need to seek green and natural alternatives. Secondly, it's vital to reduce their usage in our daily lives as much as possible, ensuring a clean and safe living environment.

The engineering geophysical exploration area is located in Wenquan Town, (see Figure 1). Jimo Hot Spring is situated on the NE edge where the Laoshan granite massif contacts with the Cretaceous intrusion. The stratum is the first section of the Formation of the Lower Cretaceous (K1q1), characterized by tuffaceous clastic rock and volcanic rock. Structurally, the work area belongs to the east Wenquan segment of the Wenquan Fault. The Wenquan Fault is the largest NE-trending fault in Qingdao, controlling the exposure and distribution of the granite. To the east of the fault is the uplift, while to the west is the Bay subsidence basin, a Level V structural unit. The fault acts as the boundary between the two. Within the area, multiple hot spring extraction wells have already been constructed. The spring water has an average temperature of nearly 70°C with a substantial flow rate. The surrounding silt deposits have therapeutic properties, making it a highly valuable mineral resource.

1. Regional Geological Overview

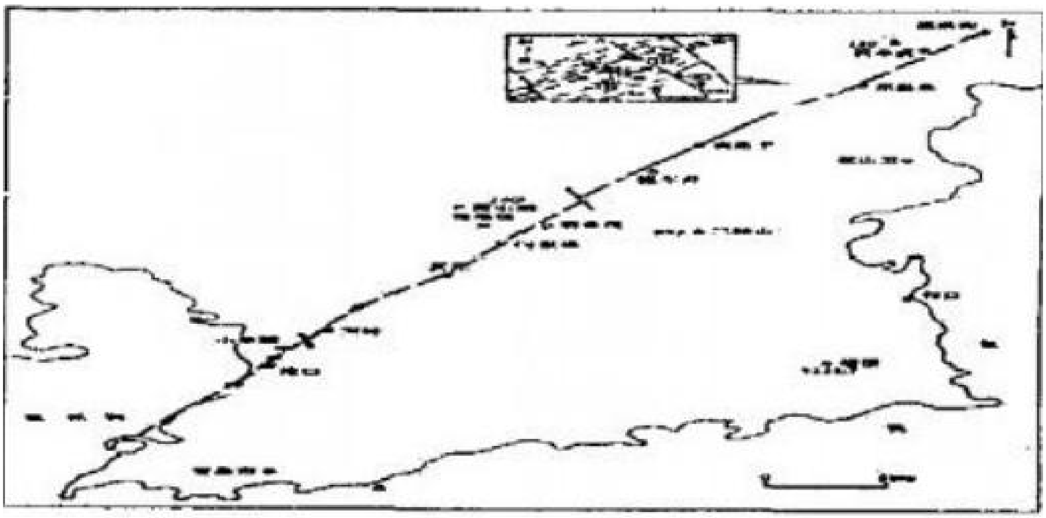


Figure 1

Certain measures can be taken to reduce or eliminate the release of formaldehyde from clothing. First, one can use dyeing and printing auxiliaries that are formaldehyde-free or have ultra-low formaldehyde content. Second, it's advisable not to use printing and dyeing auxiliaries that release formaldehyde during the finishing process or release formaldehyde under the effects of sunlight, sweat, and body temperature. Volatile organic compounds (VOCs), which have a similar polluting and toxic effect on the environment and humans as formaldehyde, have widespread industrial applications. However, their destructive potential cannot be overlooked. It is crucial to actively seek green and natural alternatives and to reduce their usage in our daily lives as much as possible. Only then can our living environment remain clean and safe.

The engineering geophysical exploration area is located in Wenquan Town, Jimo, Qingdao (see Figure 1). Jimo Hot Spring is situated on the NE edge where the granite massif contacts with the Cretaceous intrusion. The stratum is the first section of the Formation of the Lower Cretaceous (K1q1), characterized by tuffaceous clastic rock and volcanic rock. In terms of structural units, the work area belongs to the Wenquan Fault's eastern Wenquan segment. The Wenquan Fault is the largest NE-trending fault in Qingdao, controlling the exposure and distribution of the granite. To the east of the fault is the Qingdao and uplift, while to the west is the Bay subsidence basin, a Level V structural unit. The fault acts as the boundary between the two. Multiple hot spring extraction wells have already been constructed within the area. The spring water has an average temperature of nearly 70°C with a substantial flow rate. The surrounding silt deposits have therapeutic properties, making it a highly valuable mineral resource.

2. Methodology and Data Collection

2.1 Methodology

The seismic method employed in this project is the shallow high-resolution seismic imaging exploration technique. This method is one of the most effective detection techniques in shallow seismic exploration and is widely used in engineering geophysics due to its high resolution, simplicity, cost-effectiveness, and ability to provide multifaceted data, including the location of faults, their geometric shapes, and the width of fracture zones.

The principle of seismic imaging is fundamentally similar to the seismic reflection method. It utilizes reflected waves generated by subsurface interfaces with different acoustic impedances (a product of medium density and velocity) for exploration. The resulting data provides a seismic reflection time section created through near-source imaging. This seismic imaging section can continuously and real-time display acoustic impedance interfaces, vividly reproducing subsurface rock layer structures and other structural forms and distributions. Subsequent data processing can further determine the depths of underground rock interfaces, providing valuable insights for data interpretation.

During fieldwork, the electrical method measurement was based on seismic exploration. Given that the work area is located in a fault zone of the hot spring with abundant water content, the high-density electrical method was chosen for the task. The principle of the high-density resistivity method is similar to the conventional electrical method but is an improved version. The high-density electrical method is characterized by its short point distance, high data collection density, precision, and efficiency. It has gradually become a standard method in engineering geophysics for tasks such as pipeline detection, water exploration, karst studies, and geological hazard investigations.

2.2 Data Collection

During field operations, the seismic survey lines were flexibly arranged based on the surface conditions and regional geological structures within the work area. The survey lines were coded as L1, L2, and L3. The first main survey line was divided into two segments, L1 and L2, due to the influence of surface rivers, with a horizontal displacement of ten meters between them. The other main survey line was L3.

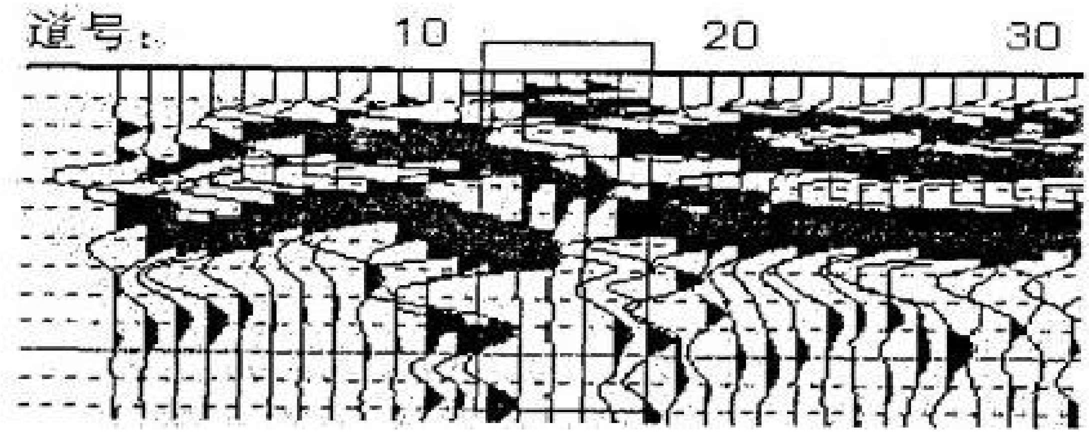
The equipment used for the seismic operation was the WZG-24 Engineering Seismograph from Chongqing Benteng Numerical Control Technology Research Institute. The data collection software was the matching WZG24 software. The method employed a sledgehammer striking a pad as the trigger, with a single geophone (38Hz) for reception, a sampling interval of 0.2ms, and 8192 sampling points. The optimal offset distance was 2m, and the channel spacing was 5m. To suppress interference from surface waves, multiple vertical stacking of hammer strikes and the combined reception of multiple geophones were used. There was minimal noise interference in the field area during construction, resulting in data with high resolution and a favorable signal-to-noise ratio.

2.3 During field operations, the layout of the high-density resistivity method was consistent with the two main seismic survey lines, spaced apart to avoid mutual interference during construction. The equipment used for resistivity measurement was the WJDJ-2 Multi-Function Digital Direct Current Stimulus Instrument as the main control unit, paired with the WDZJ multi-channel electrode converter, two power boxes, cables, and other components to form the GMD-1 High-Density Resistivity Measurement System. This system can complete electrode deployment in one go during field operations.The system integrates both emission and signal reception, making it portable with excellent anti-interference capabilities and high measurement accuracy. The system can effectively measure parameters using various electrode arrangement methods, obtaining rich geoelectric structure information. Compared to the traditional resistivity method, this system offers lower costs, higher efficiency, more abundant information, convenient interpretation, and a significantly enhanced exploration capability.

3. Data Processing and Analysis

3.1 Data Processing

The seismic imaging profile consists of near-source, single-channel seismic records arranged in sequence according to shot-point locations, resulting in a composite profile. Therefore, the accuracy and signal-to-noise ratio of the seismic signal are high. When processing seismic imaging data, basic corrections and filtering processes are typically required before converting it to a depth profile for structural interpretation. During fieldwork, surface undulations and stratum inclinations have minimal impacts on the imaging profile. However, surface reception conditions significantly influence the data. For example, concrete road surfaces, due to their high-speed characteristics, cause the entire seismic trace to compress and shift upward, leading to structural artifacts (as shown in Figure 2). Soft grasslands result in weak seismic trace energy and introduce interference. During processing, it is essential first to identify and correct for these phenomena.



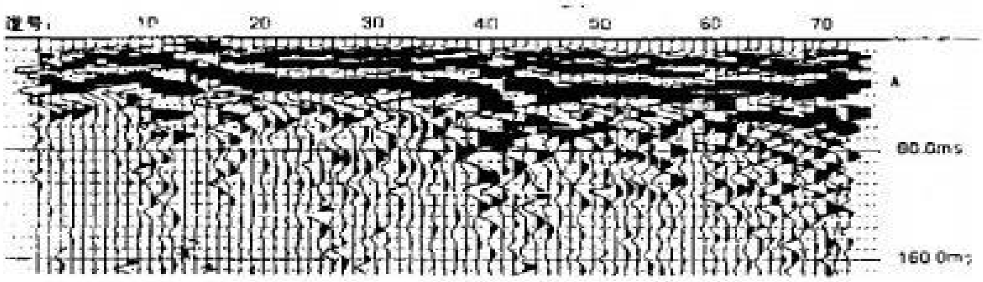
Cement road surface

Figure 2: Reflection of the road surface on the seismic profile

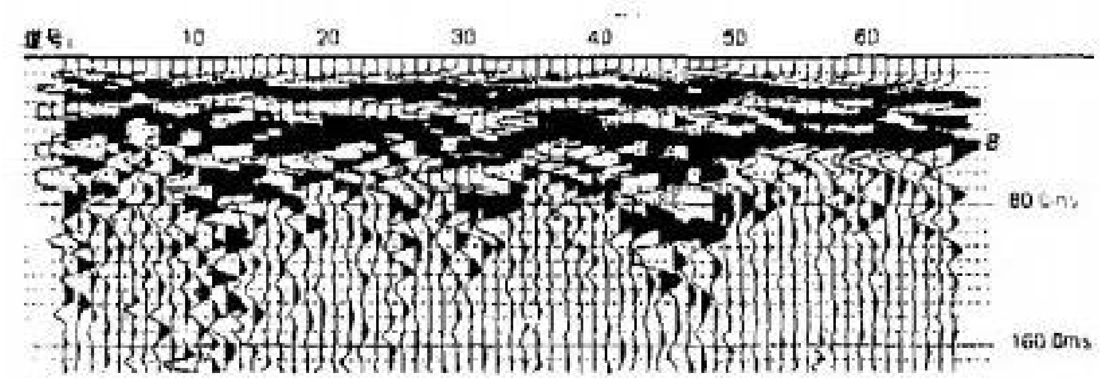
The collected high-density resistivity data is first converted in terms of data format and preprocessed. It is then processed into images using the RES2DINV 4.35 version software for two-dimensional inversion of high-density resistivity data. The inversion method used is the least squares method. Through the RES2DINV inversion software, resistivity imaging is performed, which can clearly, intuitively, and accurately reflect the resistivity distribution of the geoelectric cross-section.

3.2 Data Analysis

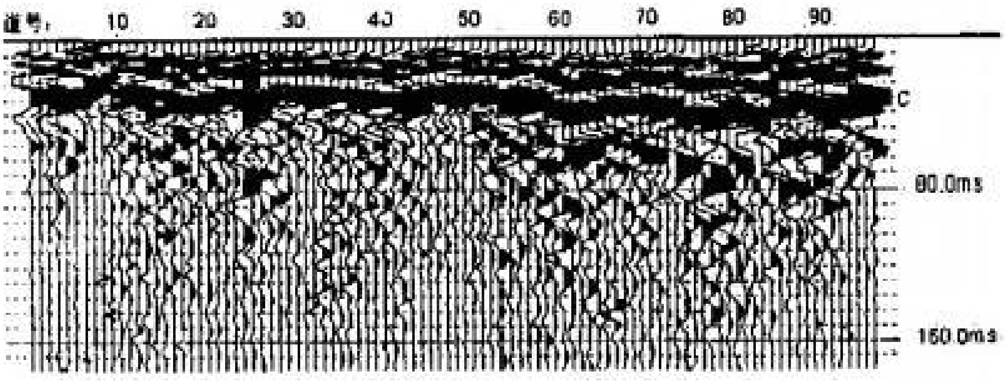
Figure 3 displays the original time record profiles of the three main survey lines. The L1 profile, corresponding to traces 14-16, shows a time low-value anomaly. A similar feature is evident on the parallel L3 survey line, specifically on traces 7-9. By comparing with the construction version report, it can be deduced that the primary cause is the high-speed characteristic of the surface concrete pavement, thereby eliminating the possibility of underground faults.



(a) Time profile of survey line L1



(b) Time profile of survey line L2



(c) Time profile of survey line L3

Figure 3 (Dashed lines in the figure are spaced at 8ms intervals, and the direction of all three survey lines is W-E)

Since the Pleistocene, the Hot Spring fault has become structurally stable and does not exhibit the characteristics of late Quaternary active faults[5]. Through existing data from the rock cores of hot spring wells, it is known that the Quaternary section of the hot spring, from bottom to top, consists of: Holocene black marine mud, brown lagoon clay, and lake fine sandy sediments. The entire Quaternary strata serve as a low-velocity layer. Thus, the boundary between the entire Quaternary and the underlying high-speed weathered base rock is an excellent reflection interface. Analyzing the original record profile (Figure 3), it is evident that the time horizons A, B, and C (i.e., strong horizons with similar phases) correspond to this boundary.

3.2.1 Distribution of Fault Zones

In Figure 3(a), the time horizon A shows a noticeable offset between traces 40-44, with a central fault displacement of around 10ms, suggesting the presence of a fault structure. Figure 3(c) represents a profile parallel to Figure 3(a) for line L3. From the figure, it can be observed that the horizon C has an offset between traces 15-17, and the deep horizons at the bottom appear funnel-shaped, displaying strong energy and poor continuity, suggesting a fault structure at this location.

Figure 4 is the high-density electrical resistivity inversion profile parallel to line L3. The red area represents the deep bedrock layers with apparent resistivity values above 70. Between 90-105m, there is a high-resistance blank zone, which corresponds to traces 15-17 of the C horizon, indicating that the electrical resistivity and seismic imaging profiles corroborate each other.

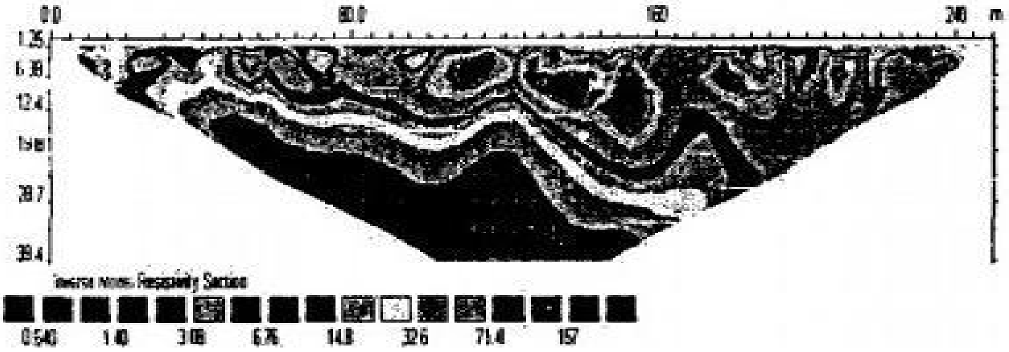


Figure4 High-density electrical resistivity inversion profile of the L3 seismic line.

The anomalies corresponding to the above two measurement line locations are connected in a slightly eastward direction, where there is a hot spring water intake well built by the local unit. From the wellhead core, it is identified as fault breccia composition. Based on the above, it can be confirmed that this is the western boundary of the Hot Spring fault zone. In Figure 3, both the 44-48 traces of the isochronous axis B and the 84-86 traces of C show the same characteristics as the above two anomaly points, inferring that the line connecting the two points is the eastern boundary of the fault zone. It can be seen that the fault zone extends in the NE direction along the above two boundaries.

3.2.2 Fracture Characteristics Within the Fault Zone

In figures 3(b) and 3(c), the reflection horizons B at locations near traces 10, 17, and 28, as well as reflection horizons C near traces 68 and 75, all exhibit significant discontinuities and misalignments, suggesting the presence of faults at these locations. These minor fault structures reflect the intense fracturing characteristics of the fault, indicating that the formation of the Qingdao Jimo Hot Spring fault was under strong tectonic stress and experienced intense activity.

3.2.3 Underground Thermal Water Distribution Characteristics

In addition to defining the boundaries of the fault zone and verifying the accuracy of seismic imaging, the electrical method can also provide a direct representation of subsurface water distribution. Analyzing Figure 4, the shallow part between 100-215m along the profile is characterized by a low resistivity zone, reaching its maximum depth near 20m. This low resistivity zone has a broad distribution area. The location of the surface hot spring well is around 105m, confirming that the low resistivity anomaly represents an underground hot spring water accumulation zone. It can be observed that the hot spring water within the controlled area of the survey line is roughly divided into five water accumulation bands, with the most abundant water between 100-160m.

This can serve as a basis for the rational utilization and development of hot spring resources.

4. Conclusion

The application of geophysical methods in the hot spring fault zone area can achieve excellent results. The comprehensive use of various methods further enhances the final interpretation's accuracy and simultaneously addresses multiple practical issues. However, it's worth noting that results obtained from geophysical methods inherently have multiple interpretations, and it is essential to validate them with drilling data. Owing to their high precision and low cost, geophysical methods will play a vital role in resource exploration and engineering surveys.