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Comparisons of MT Array Results with Drillings in Taiwan

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ABSTRACT

Taiwan has a high population density and complex mountainous terrain. Magnetotelluric (MT) Array hardware system and data processing software were developed in order to improve the signal to noise ratio for the Magnetotelluric survey and to work in the rough terrain area. The effective apparent resistivity with respect to frequency from several MT Array surveys was compared with the data previously drilled by Chinese Petroleum Corp. and Industrial Technology Research Institute. The results from the MT Array could explain why those wells are not successful.

1. INTRODUCTION

The most common MT exploration used is by remote reference assuming the reference site is with very small noise and the magnetic field has the same plane wave. The MT Array developed by 3JTech was designed to improve the resolution of MT readings in areas like Taiwan where the noise is high and land with enough open space is scarce.

The basic concept of 3JTech MT Array is the simultaneous recording at the sites of at least 3 MT stations which is applied to remove the uncorrelated local noises. The identified noise is then removed and replaced by the data from a prediction filtering software. The simultaneously recorded data are used for stacking to yield further higher signal to noise ration and thus higher exploration resolution

2. MT ARRAY RESULT AT HONG-TSAI-LIN (HTL) AREA, I-LAN, NORTHEAST OF TAIWAN

Two deep geothermal wells, HTL #1 and HTL #2, were drilled in the Northeast Taiwan (Figure 1) by the Geothermal Drilling Project under National Energy Program after carrying out different exploration methods. The separation of the two wells is about 1.5 kilometers. Well HTL #1 was drilled to a depth of 2,200 meters with highest measured temperature of 70^{o}C at the bottom of the well. The well did not discharge. Well HTL #2 reached to a total depth of 2,800 meters with a maximum measured temperature of 120^{o}C at the bottom of the well. HTL-2 is quite fractured (Wang, Chien-Ying; 2017). It meets an obvious fracture zone between 1,800 m and 2,300 m. According to the analysis of core cuttings and well logging, the strata encountered are 1) the alluvial layer (sandy mudstone in the upper half and gravel in the lower half), 2) KanKo formation (Kk, mainly slate), 3) the SuLin formation (Sl, mainly quartz sandstone) and 4) HsiChuan formation (Ht, slate-based). The Sl formation is quartz sandstone which is extremely hard and quite difficult to drill and sampled. The depths of this formation are: HTL-1 (330m, 1,280m, 1,970m) and HTL-2 (470m, 1,310m, 2,280m). HTL-1 is hard and completely with no obvious fractures While, HTL-2 is quite fractured between 1,800m and 2,300m. HTL-2 discharge clean water with a flow rate of 130 tons / hour without obvious calcium or silicate precipitation. It is believed that the well intersected a fault, probably the LanYangRiver fault.

From our MT Array result as shown in Figure 2, it shows no evidence of geothermal reservoir around the two wells. In Figure 2, the effective apparent resistivity is used. The vertical scale is in log10[frequency]. The frequency range s from 400 to 0.001 Hz. HTL #2 is close to a low resistivity zone at the local surface. It may explain why HTL #2 is better in temperature and flow rate. There is a low resistivity zone along line A-A' on the surface in a NW-SE direction located in the southwest of the drilling sites. The low resistivity seems to represent a fault with local alteration on the formation near the surface from the hot fluid.

3. MT ARRAY RESULT AT AT CHIH-PEN, TAIDONG, EASTERN PART OF TAIWAN

MT Array was carried out around in Chih-Pen Well #1, Taidong, Taiwan. The geographic locations of the MT stations, the well and the profile B-B' are shown in Figure 3. Figure 4, represents the well temperature logging data and the temperature profile B-B' along east – west direction. It could be seen that the temperature from the logging data decreased starting from about 250 meters. The dashed oblate on Figure 4 was interpreted as the shallow reservoir for the well-known Chih-Pen hot spring resort. At the right-hand side of the oblate, there is no hot spring resort. According to Wang, Chia-Pin (1987), the shallow hot water comes from Jian-Chin fault as shown on the right-hand side of Figure 4.

Figure 5 represents an effective apparent resistivity distribution with respect to frequency from the MT Array along B-B' profile. The red zone on the upper left of the Figure coincides with the location of hot spring reservoir at shallow depth. From the current data, the heat source seems to be very deep and the evidence for the channels between the heat sources and the shallow hot spring reservoir is very weak. More MT survey is suggested and the induction vector could be applied to delineate the channels between the heat source and the shallow hot spring reservoir.

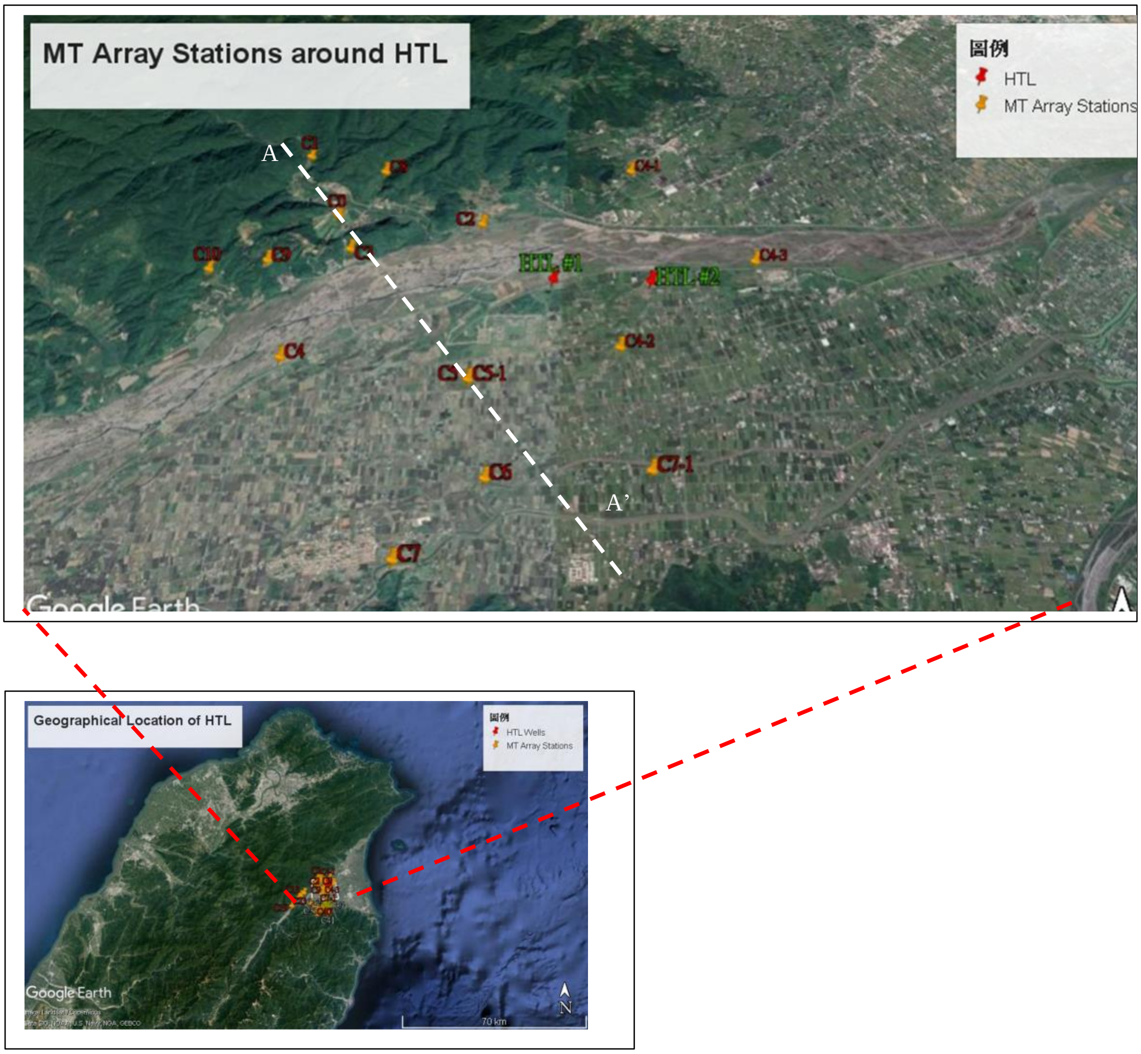

Figure 1：Geographical location of HTL Well #1 and #2. Line A-A’ represents a fault from the survey shown on the Figure 2.

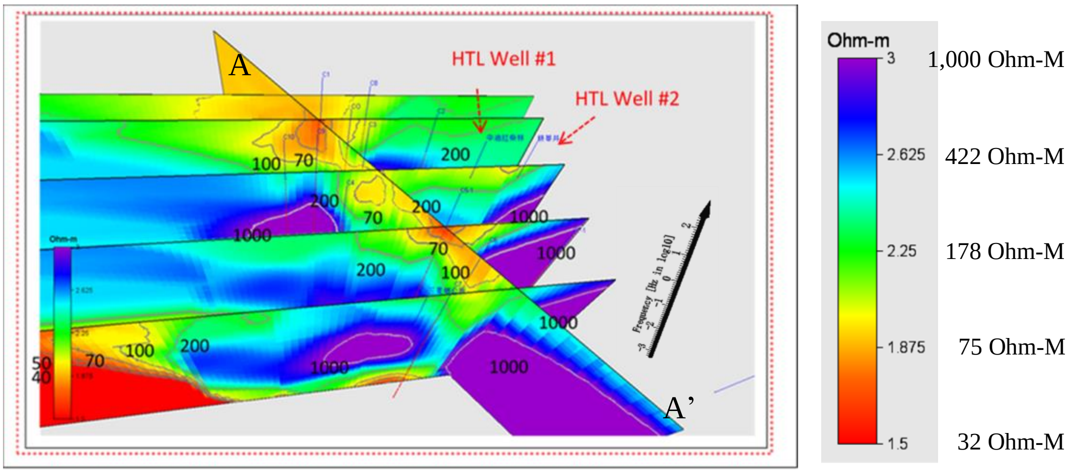

Figure 2：Effective Apparent Resistivity Distribution with respect to frequency around HTL Well #1 and #2. The vertical scale is in log10[frequency]. The frequency range s from 400 to 0.001 Hz. The low resistivity zone along line A-A’ seems to represent a possible fault.

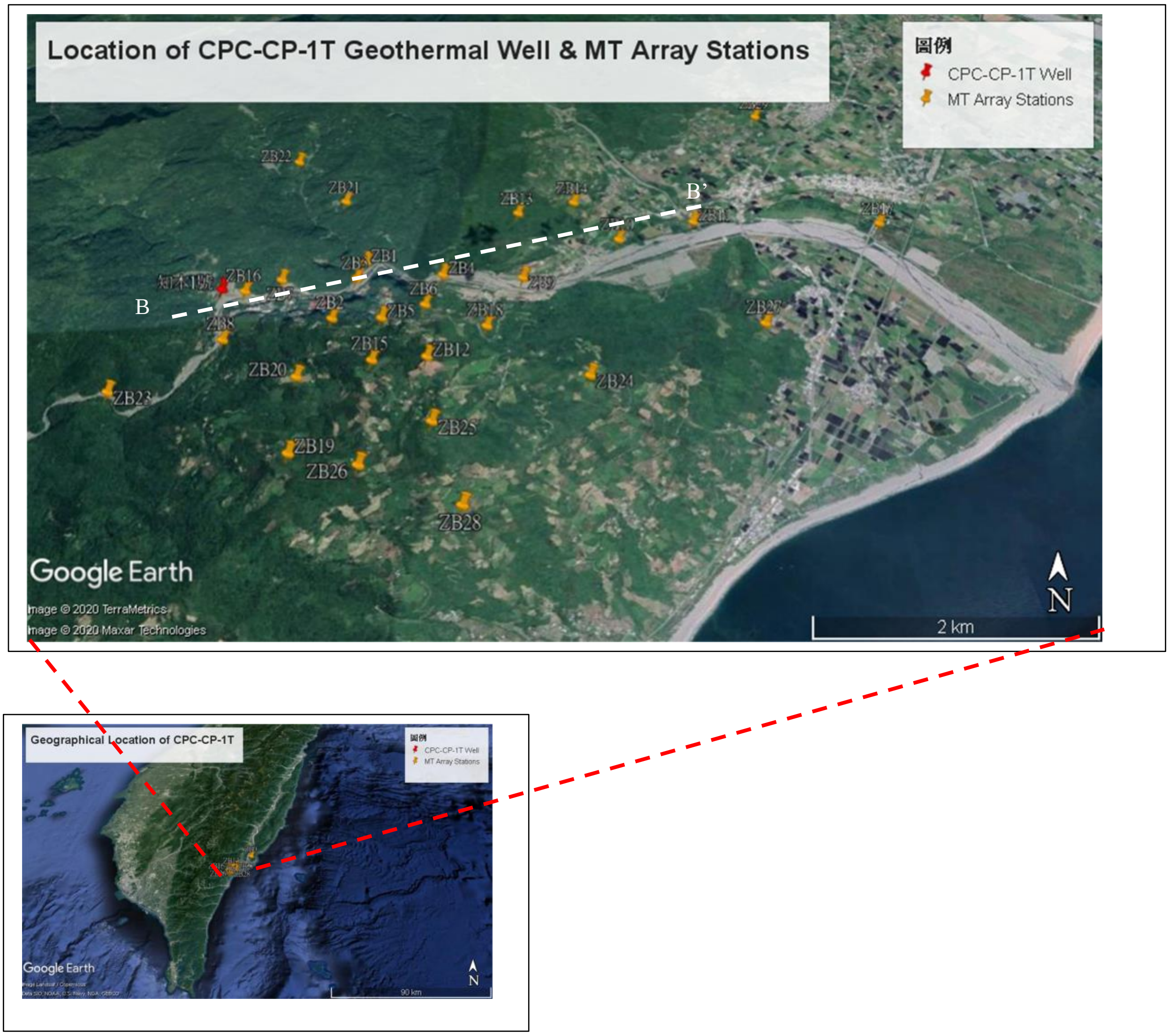

Figure 3：The figures show the geographical locations of CPC-CP-1T geothermal well and the MT Array Stations. Also shown is the location of B-B' profile.

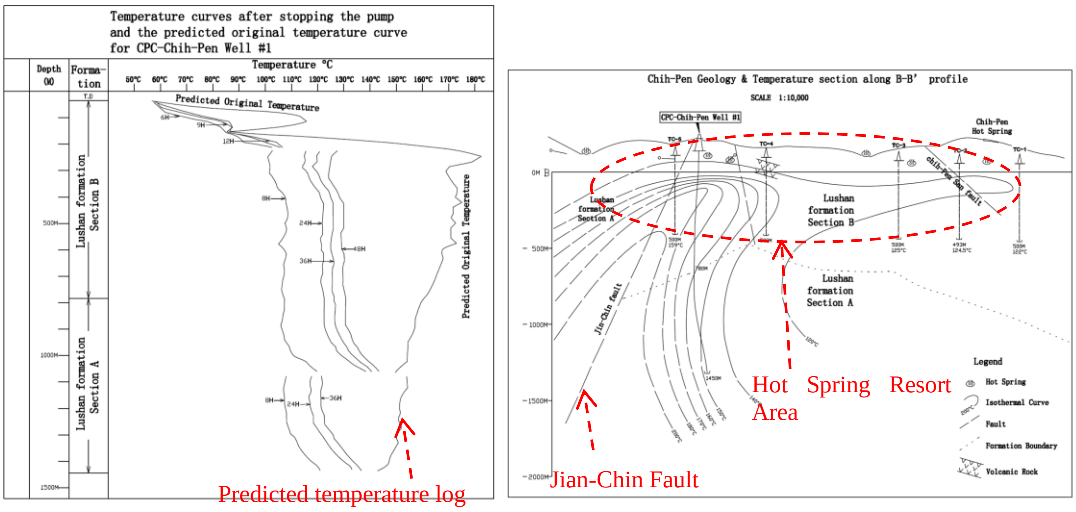

Figure 4：The left represents the temperature logging of CPC-CP-1T geothermal well. The right represents the temperature profile along line B-B' in Figure 3. The dashed oblate is the known reservoir for Chih-Pen hot spring resort.

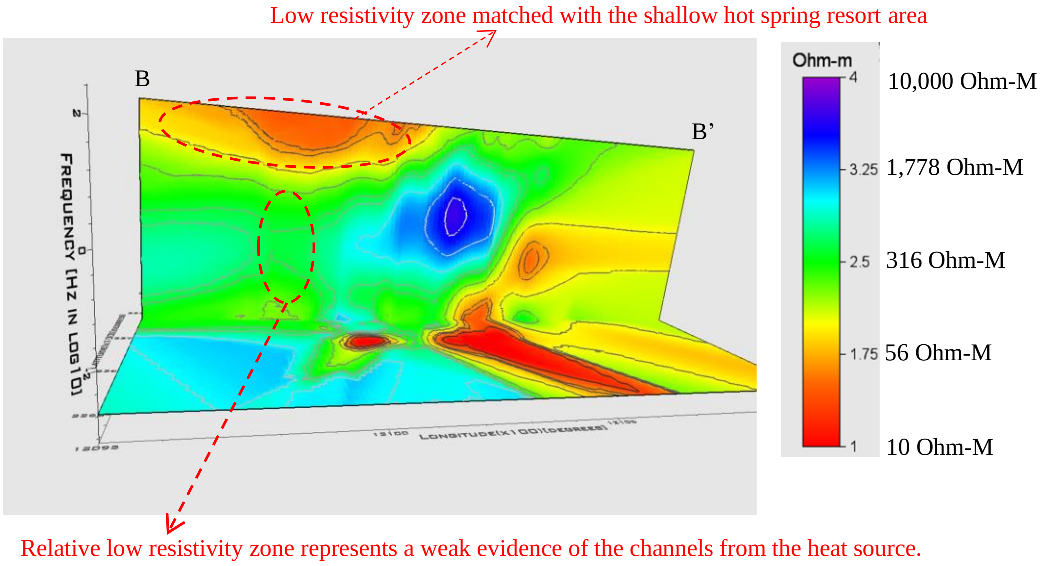

Figure 5：The effective apparent resistivity distribution with respect to frequency from the MT Array along B-B' profile as shown on Figure 3.

4. MT ARRAY RESULT IN DATUN VOLCANIC AREA AROUND CPC JINSHAN #1 AREA

MT Array survey was carried out in the Datun volcanic area in the northern part of Taiwan. The geographical location of the deep well, CPC Jinshan #1, is shown in Figure 6. Figure 7 shows the effective apparent resistivity distribution with respect to frequency along profile A-A' with interest on CPC Jinshan #1 well. Figure 8, is the temperature profile for well CPC Jinshan #1 with respect to depth from Wu, Kuan-Hon (1980). One could see the temperature drops from about 350 to 850 meters, representing the cold water injection. It stat to increase again from about 900 meters.

From the effective apparent resistivity distribution, there is no low resistivity clay as the cap rock. There is a low resistivity layer, probably represent the alteration zone and represents part of the volcanic neck extended from the crater. This low resistivity layer might also explain the acidic zone from the logging data. Below the alteration zone, there is a neutral high resistive zone. The right-hand side of the profile is high resistive, representing different geological formation.

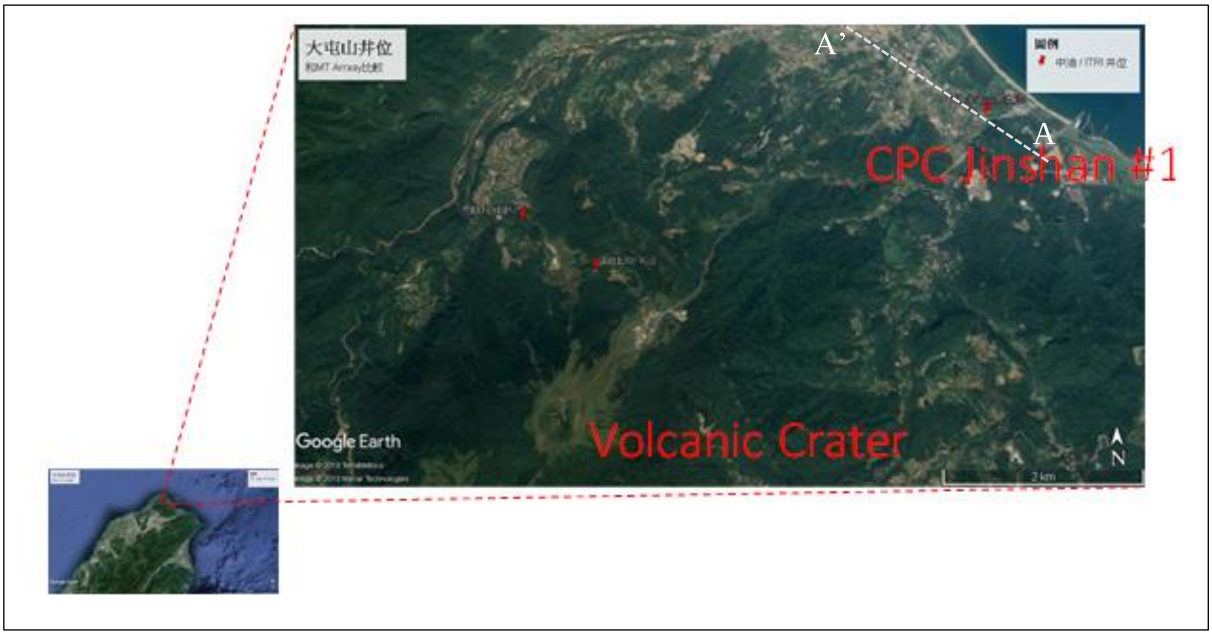

Figure 6：Geographical location of the deep well, CPC Jinshan #1 and the A-A' profiles in the northeast part of volcanic crater.

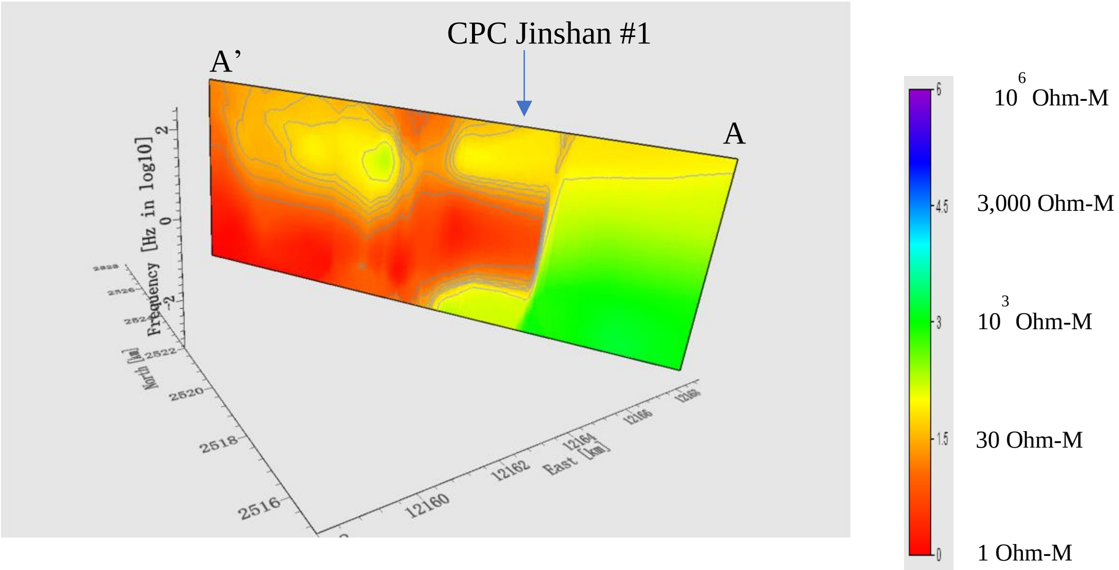

Figure 7：The apparent resistivity distribution with respect to frequency along profile A-A’ interest with CPC Jinshan #1 well.

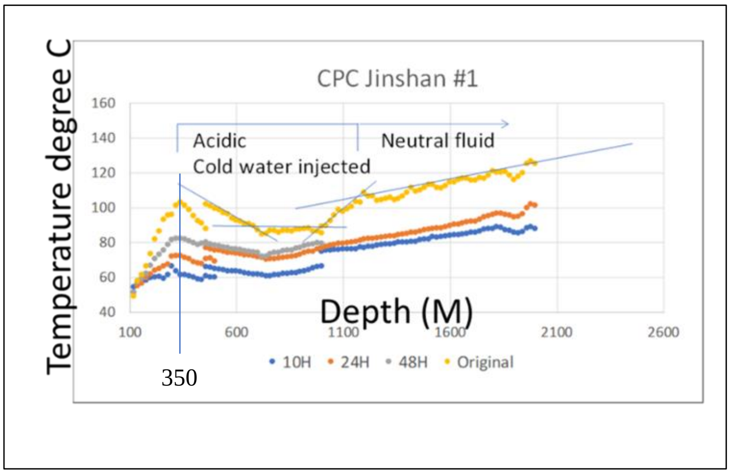

Figure 8： Temperature logging curves for CPC Jinshan #1 well

6. CONCLUSION

The MT Array are used to de-spike the local noise and enhance the signal noise ratio. The surveys use effective apparent resistivity with respect to frequency to compare with the drilling results for qualitative interpretation. The results show that the drilled wells are located outside of the delineated possible geothermal reservoir. This could explain why the drilled wells are not successful for geothermal development.

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