Proc. 10th New Zealand Geothermal Workshop 1988

MAPPING OF LOW TEMPERATURE PROSPECTS BY COMBINED TP/RESISTIVITY SOUNDINGS (ELECTRICAL FACTOR METHOD)

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ABSTRACT

Low temperature prospects standing in clay-rich country rocks or rocks saturated with saline pore fluids produce, in general, rather indistinct resistivity anomalies. Laboratory tests have shown that the ratio of apparent polarizability (rj_a) and apparent resistivity (p_a), here defined as combined electrical factor F = (Ha/Pa)' *s not much affected by the concentration of the electrolyte but increases almost linearly with temperature.

Field surveys using combined DC and IP soundings have shown that distinct high F-anomalies can be obtained over a low temperature prospect (Xiamen City in Fujian Province) where the country rocks are saturated with diluted sea water causing a rather indistinct low apparent resistivity pattern. The method has also been tested over a few other low temperature prospects, namely Xiaotangshan near Beijing and at Zhangzhou City in Fujian Province, in both areas rather high F-anomalies were found to be associated with shallow thermal waters.

METHOD:

DC - electrical surveys are still the most effective geophysical method presently used for geothermal prospecting. In general, low resistivity anomalies can be observed over reservoirs saturated with thermal fluids, even in the case of low temperature prospects. In some cases, however, such as prospects standing in clay-rich country rocks or in rocks saturated with saline pore fluids, the apparent resistivity anomalies over low temperature prospects can be rather indistinct.

In order to reduce the influence of low resistivity rocks, the combined electrical factor (F) method has been developed by the first author since 1983. The method is based on simultaneous resistivity and IP (induced polarization) soundings and plotting of the ratio of $T|_a$ (apparent polarizability) and p_a (apparent resistivity) versus spacing factor of current electrodes (AB/2) in a section, the ratio (Tja/pa) for a given spacing AB/2 is defined here as the combined electrical factor F (i.e. F = ^*Ip*^-

The resistivity of an electrolyte and the polarizability of a conductive rock saturated with an electrolyte and containing a conductive matrix are both temperature dependent. Laboratory studies of rock samples saturated with an electrolyte have shown that the temperature effect in resistivity and polarizability can be enhanced if the ratio of $T|_a$ and p_a is used. Fig. 1 shows the results of a laboratory experiment where Ti_a and p_a together with the ratio $F = T|_a/p_a$ are plotted. Other similar tests showed that the magnitude and the trend of the F-factor, which increases almost linearly with the temperature of the pore fluids, does not change significantly with the concentration of the electrolyte. This is shown in Fig. 2 where the results of measurements are shown for the same rock sample whose concentration of electrolyte (Na Cl) was increased by about one order of magnitude. These laboratory tests indicate that conductance anomalies caused by changes in temperature could be mapped by the F-factor method even in the presence of lateral changes in the concentration of pore fluids.

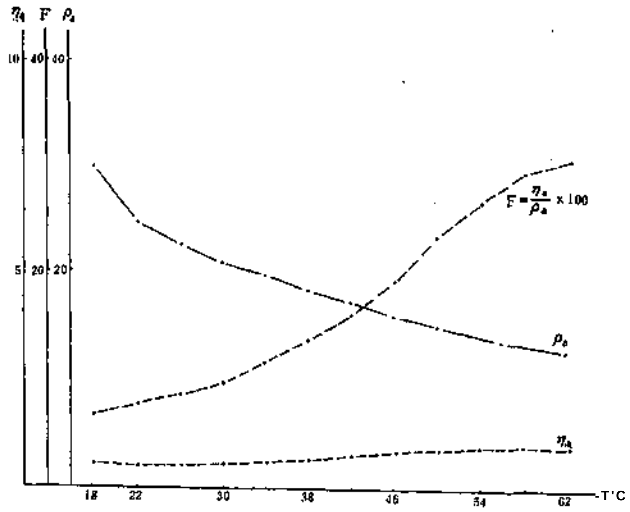

Fig. 1: The relationship between p_a, $r\backslash_a$, F and temperature as measured in the laboratory at a rock sample.

RESULTS OF FIELD TESTS:

The method has been used successfully in the exploration of ten low temperature prospects in China. In the Xiaotangshang prospect (see Fig. 3) hot water occurs near the top of permeable Sinian dolomites which are covered by 300 to 500m thick sediments. Hot water ascends through the sediments and is discharged in nearby hot springs. A section of the F-factor values plotted versus spacing AB/2 is shown in Fig. 3; the highest F values occur near Well 32 which encountered the highest temperature in the basement aquifer. Recently a new well was drilled in the nursery of the Xiaotangshang sanatorium on top of the F-factor anomaly; the well was productive and encountered thermal water with a temperature of *56°C* at 480m depth.

Another example of a field survey is shown in Fig. 4 which shows various geophysical anomalies over a thermal prospect in Xingling Bay near Xiamen City (Fujian Province). Here thin sediments underlain by granites have been infiltrated by some seawater; the apparent resistivity anomaly, showing apparent resistivities as low as 6 ohm m, is not well defined but the F-factor plot outlines clearly a highly anomalous area beneath stations S1 and S2. Hot water is discharged by a hot well (Wl) which shows up in a shallow temperature survey.

Other examples of field surveys using the F-factor method are a survey of the Lingpo hot springs in Zhangzhou City (Fujian Province); based on the results of the F-factor method a well was drilled which encountered hot water with a temperature of 102°C at 155m depth.

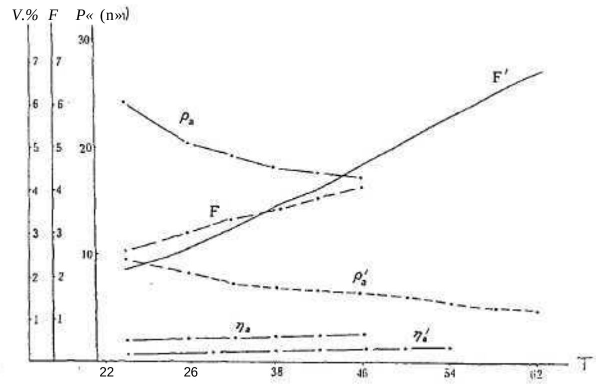

Fig. 2: Changes in ρ_a, η_a, F as measured in the laboratory for two concentrations of pore fluids (NaCl); the primed parameters refer to the higher concentration (1000 mg/kg).

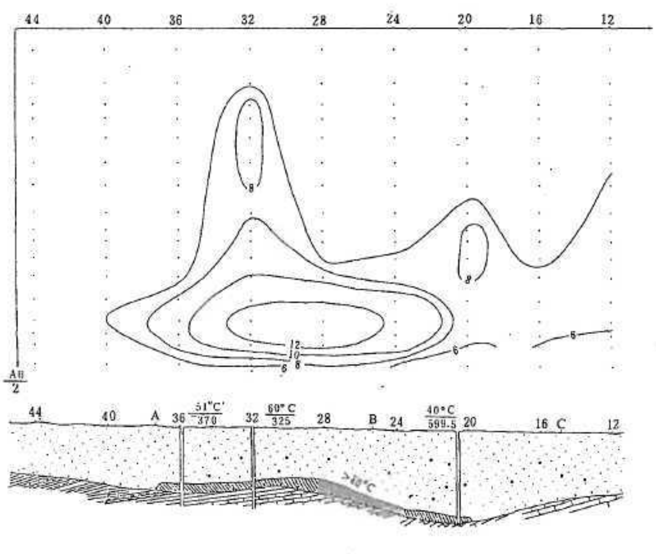

Fig. 3: Plot of the F-factor along a profile across the Xiaotangshan hot spring area; the geological section is shown in the lower half.

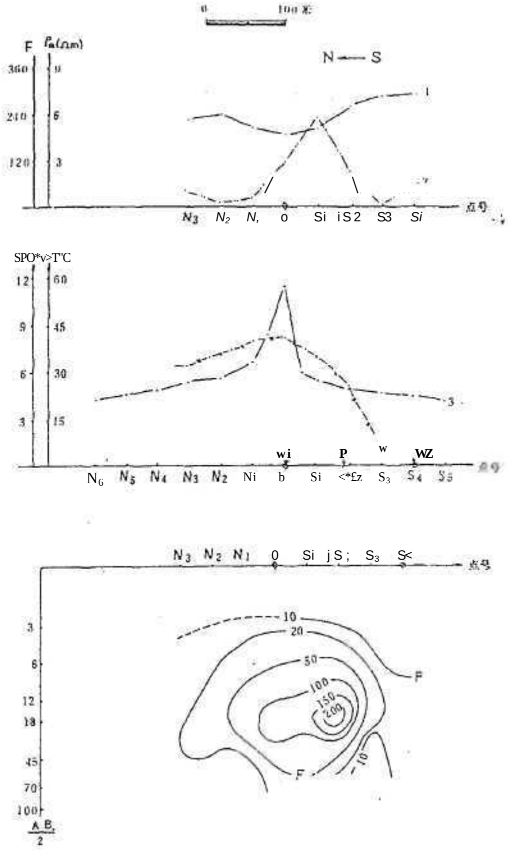

Fig. 4: Geophysical anomalies across a profile in Xingling Bay (Xiamen City), profile 1 is the apparent resistivity, 2 the F-factor, 3 the shallow temperature, and 4 the SP anomaly. W2 denotes a cold well, Wl a hot well, and P a natural hot spring. The F-factor section plot is shown in the bottom part of the figure.

SUMMARY:

Preliminary studies in the laboratory and in the field have shown that resistivity anomalies caused by thermal waters can be mapped with the combined electrical factor (F factor) method. The F-factor, given by the ratio of apparent polarizability and apparent resistivity for a given linear sounding array, enhances conductance anomalies caused by temperature-dependent changes of the pore fluids and produces distinct anomaly patterns which are related to the temperature structure of low temperature prospects even if they stand in clay-rich country rocks or rocks saturated with saline pore fluids. Further research is required to understand why the F-factor is so sensitive to changes in pore fluid temperature.