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A new approach for geothermal gradient assessment based on slate peak metamorphic temperature of geothermal well core

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Geologic and geochemical surveys plus borehole temperature logging constitute primary methodologies for establishing the local geothermal gradient, essential for assessing thermal resources in potential geothermal areas. Assuming thermal equilibrium of geothermal fluid within its genetic environment, and minimal influence from shallow fliud sources, geochemical analysis aids in estimating reservoir temperatures. However, deviations arise if meteoric water impacts ion percentage concentrations, leading to miscalculated reservoir temperatures and misestimations of geothermal resources. Furthermore, these calculated reservoir temperatures are unsuitable for inferring the depth of geothermal fluid generation through geochemistry alone. In addition to geochemical methods, temperature logging in shallow or exploration wells offers an alternative approach to infer the geothermal gradient. Nonetheless, the accuracy of temperature gradient estimates in deeper environments depends on well depth, potentially resulting in higher drilling costs. The presence of shallow fluid further introduces deviations in the inferred geothermal gradient. This study proposes a new approach for geothermal gradient assessment based on the peak metamorphic temperature of slate. Utilizing Raman spectroscopy of carbonaceous material (RSCM), the peak metamorphic temperature is determined with high precision within the suitable range of 200~600°C. The method's uncertainty, approximately 10-15°C among measured samples, allows identification of subtle variations in metamorphic degree. Carbonaceous material (CM), prevalent in pelitic rocks, undergoes irreversible and temperature-controlled graphitization during metamorphism, and graphite represents its most stable state in the lithosphere. Therefore, by measuring the Raman spectra band parameters of graphite in slate under optical thin sections, the corresponding peak metamorphic temperature can be inferred using an empirical formula. Given that many geothermal potential areas in Taiwan are located in the slate-dominated Backbone Range and Husehshan Range due to rapid exhumation, this method exhibits potential and feasibility for evaluating and developing deep geothermal resources in Taiwan. This study involves the analysis of five distinct-depth slate core samples extracted from an 800-meter-depth exploration well in Hongye, Taitung. The peak metamorphic temperatures of these samples are measured and calculated, which are approximately 330°C. In addition to the peak metamorphic temperatures, the logging temperatures at the well's top and bottom are considered as constraint points. These values are incorporated into a three-dimensional homogeneous heat conduction formula, yielding a function depicting ground temperature in relation to depth. This derived function serves as valuable background geothermal information, which can be applied to the evaluation of future deep geothermal resources.

Keywords: geothermal exploration, geothermal gradient, Raman spectroscopy on carbonaceous material, peak metamorphic temperature