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Heat flow, deep formation temperature and thermal structure of the Tarim Basin, northwest China

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Geothermal regime of a sedimentary basin not only provides constraint on understanding the basin formation and evolution, but also offers fundamental parameters for hydrocarbon resources assessment. As one of three Precambrian blocks in China, the Tarim craton is also a current hydrocarbon exploration target where the largest sedimentary basin (Tarim Basin) develops with great potential. Although considerable advancement of geothermal regime of this basin has been made during the past decades, nearly all the temperature data in previous studies are from the exploration borehole formation testing temperatures. Recently, we have conducted the steady-state temperature logging in the Tarim basin, and measured abundant rock thermal properties, enabling us to re-visit the thermal regime of this area with more confidence.

Our results show that the present-day geothermal gradients for the Tarim Basin vary from 23 K/km to 27 K/km, with a mean of 22 K/km; the values of heat flow range from 40 mW/m2 to 49 mW/m2, with a mean of 43 mW/m2. These new data confirmed that the Tarim Basin has relatively low heat flow and shares similar geothermal regime with other Precambrian cratons in the world. In addition, the new temperatures from the steady-state logs are larger than the bottom hole temperatures (BHT) as 22 degree Celsius, indicating the thermal non-equilibrium for the BHTs used in previous studies.

Spatial distribution of the estimated formation temperatures-at-depth of 1$\sim$5km within the basin is similar and mainly controlled by crystalline basement pattern. Generally, the temperatures at the depth of 1km range from 29 to 41 degree Celsius, with a mean of 35 degree Celsius; while the temperatures at 3km vary from 63 to 100 degree Celsius, and the mean is 82 degree Celsius; at 5km below the surface, the temperatures fall into a range between 90 and 160 degree Celsius, with a mean of 129 degree Celsius. We further proposed the long-term low geothermal background and large burial depth are the favorable conditions for hydrocarbon generation and preservation.

As far as heat budget of the Tarim Basin is concerned, the radiogenic heat from the sedimentary cover accounts only for 20 percent of the surface heat flow ($\sim$9 mW/m2), while the mantle heat flow is estimated to be low as 6$\sim$15 mW/m2; this indicates the dominant contribution of crustal radiogenic heat to the observed heat flow. Any variations in surface heat flow for the Tarim Basin can be due only to changes in crustal heat production.

Thermal contrast between the Tarim Basin and Tibet Plateau, represented by a difference in surface heat flow and deep crustal temperature, is remarkable. This inherited thermal contrast can be traced as far as before the India-Asia collision. Moreover, the lithosphere beneath the Tarim Basin is sufficiently strong to resist the gravitational potential energy difference and tectonic forces from Tibet. The observed thermal and rheological contrast accounts for the differential Cenozoic deformation in the Tarim Basin and adjacent areas.