ISSN:2790-1688 DOI: 10.56028/aetr.2.1.1

Geothermal and thermal history in sedimentary basins

Zhiyuan Wu[a,*], Huanlai Zhu[b]

School of Earth Sciences, Northeast Petroleum University

[*,a] sddpshzzy@163.com, Tel:+(86) 15269888816

[b]465336292@qq.com, Tel:+(86) 13504897322

Abstract. Resources, energy, disasters and environment are big problems facing mankind today. Energy conservation, emission reduction and climate change make the development and utilization of new and renewable energy sources, including geothermal energy, become an important strategy for the energy development of all countries in the world.Geothermal and oil are two resources that coexist in sedimentary basins, and they are also a state where old and new energy sources coexist.Nowadays, the booming development of geothermal science has provided new ideas for the solution of the energy crisis, but limited by technology, geothermal and other new energy sources still cannot completely replace the old energy sources such as oil.At the same time, in the process of geothermal development, the coordinated development of geothermal Wells and oil and gas Wells and the geothermal exploration of hydrocarbon source rock development have become the new situation of geothermal and oil and gas development.In the sedimentary basin, the oilfield distribution area of the sedimentary basin is often the widespread distribution of geothermal resources, and the two resources are symbiotic.In the process of alternating old and new energy sources, the cooperation between the two has become the most popular trend of energy utilization.This paper briefly introduces the construction of ancient geothermal field in geothermal energy, which provides a brief summary of geothermal method in the development and utilization of hydrocarbon source rocks.

Keywords: ancient geothermal temperature, thermal history, sedimentary basin, oil and gas, geothermal fluid

1. Foreword

Wang jiyang academician in professor Li Siguang advocated China geothermal research, points out that the geothermal research includes the earth heat flow research, deep heat flow research, regional geothermal field research, geothermal numerical simulation, geothermal experiment and test system, geothermal resources research, mine geothermal research and oilfield geothermal research eight parts.At the same time, China's main oil and gas areas are rich in medium-low temperature geothermal resources.In recent years, the research on the exploitation and utilization of geothermal resources in oil areas has been in full swing in China. The exploration and evaluation of geothermal resources potential in oil-containing basins is the basis of geothermal exploitation and utilization in basin areas.Thus derived some new theories.Geothermal science of sedimentary basin includes heat transfer, rock thermal property, geothermal measurement and earth thermal current distribution, deep temperature and lithosphere thermal structure, basin thermal history and rock thermal evolution of hydrocarbon source, geothermal resources, etc

Thermal history of sedimentary basin refers to the thermal situation that has appeared in a certain period of geological history, including the evolution history of basin geothermal temperature and heat current evolution history.At present, the international methods of basin thermal history recovery can be divided into two categories: one is to use various ancient temperature scale or geological thermometers to calculate the thermal history, which mainly includes organic matter maturity index and mineral low temperature thermal age ancient temperature scale; the other is the thermal dynamic model of basin evolution to restore the thermal history.Basin thermal history is often one of the key factors in the maturation and transformation of organic matter in the sedimentary rocks of oil-bearing basins.At present, with the increasing difficulty of oil and gas exploration, the exploration center gradually turns to the deep ocean and basin, and the research of

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ancient geotemperature in oil and gas exploration and application has developed rapidly.At present, China has gradually formed a variety of thermal history and basin structure-thermal evolution simulation.However, in general, the research of ancient geothermal in oil and gas fields is still a weak link in China. Further research work is needed in both ancient geotemperature research methods and basin research

2. Rock thermophysical parameters

2.1 Rock thermal conductivity

Rock thermal conductivity K represents the characteristics of rock heat transfer, whose physical significance is: the heat flow rate passing per unit time when the temperature difference between both sides of the rock along the heat conduction direction is 1℃, in W / (m • K).The thermal conductivity of different rocks varies greatly (Figure 1).In general, loose substances such as dry sand, dry clay, and soils have the lowest thermal conductivity.Among sedimentary rocks, coal has the lowest thermal conductivity, followed by shale, mudstone, quartzite, salt rock and gypsum, and sandstone and conglomerate greatly.The thermal conductivity of magmatic and metamorphic rocks is generally 2.1~4.2 W / (m • K), the thermal conductivity of gas is 0.0005~0.5 W / (m • K), and that of liquid is 0.08~0.6 W / (m • K)

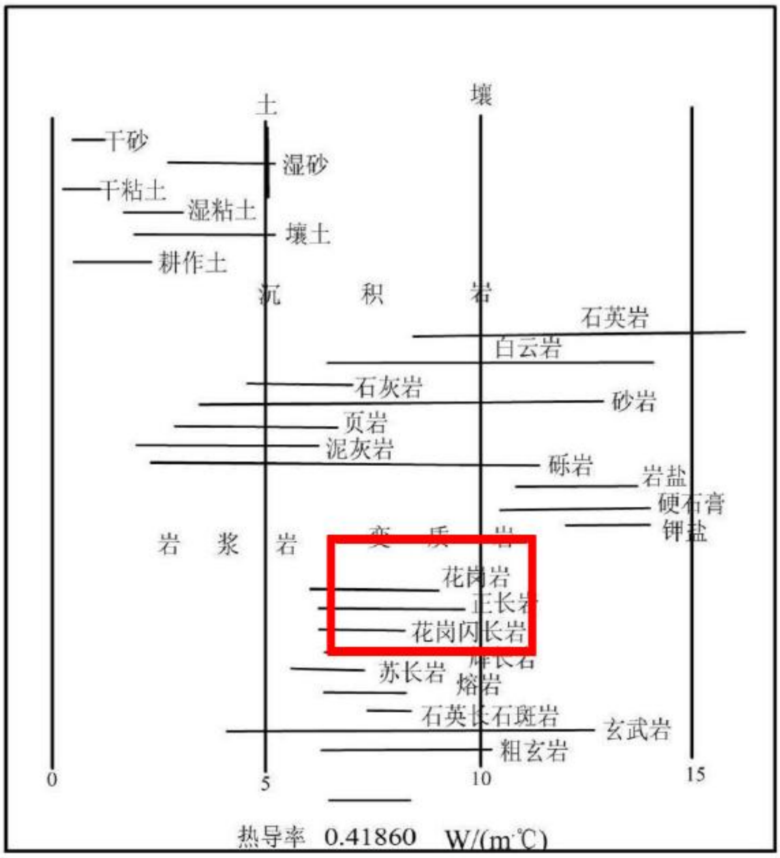

Figure 1 Changes of thermal conductivity of various rocks

Nowadays, the common test methods of rock thermal conductivity at home and abroad mainly include mobile heat source method, laser flash method, instantaneous plate heat source method and probe method.The mobile heat source method belongs to the non-stable thermal conductivity test method, and the most common mobile heat source method test instrument is TCS (thermal

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conductivity scanning).TCS (Figure 2) has the advantages of no contact, no damage, high accuracy, high precision, high efficiency, and no special processing before the test, so it is particularly suitable for testing the thermal conductivity of complete core, core terminals and core fragments.

Figure 2. T C S rock thermal conductivity tester

The TCS is able to measure the thermal conductivity and thermal diffusivity of anisotropic rock samples, thus yielding the thermal conductivity and thermal diffusion coefficient components in all directions of space.Two infrared temperature sensors and a laser point heat source exist on the TCS tester.Before testing, appropriate rock samples shall be obtained over 40mm, and the surface shall be smooth as far as possible, and the dust shall be removed. The lithology of rock samples shall be determined and selected. After sampling, 20mm wide black paint shall be applied on the rock surface and dried before testing.The testing process requires debugging the sensor and testing the standard samples to reduce errors.The test principle is to measure the temperature of the pre-cooling sensor, and after the heat source is heated, the heat sensor is measured again, so as to obtain the appropriate thermal conductivity value.Figure 3 shows a section of rock sample taken from well Sa 32.

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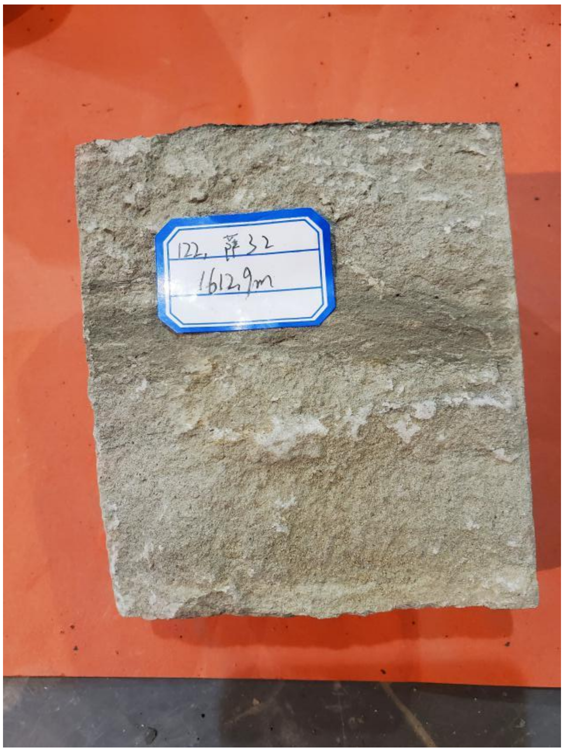

Fig. 3 A rock sample taken

There are many factors affecting the thermal conductivity of the rock, including the temperature, pressure, the characteristics of the rock itself, the degree of compaction into the rock evolution, but mainly the composition and structural characteristics of the rock.In the dense rocks, the properties of minerals mainly control the thermal conductivity, including the rock structure, and the porosity and its characteristics in the loose and porous rock.

2.2 Radioactive thermogenesis of rocks

The radioactive thermogenesis of rock is the energy released by the radioactive elements per unit volume per unit time. There are many radioactive elements in the rock, but not all radioactive elements contribute to thermogenesis.It must have three conditions: ① has sufficient abundance; ② produces large heat; ③ half-life and the age of the Earth.So the only radioactive elements contained in the rocks are uranium, thorium and potassium related to the earth's internal heat source.

The radioactive thermogenesis of rocks is generally calculated by measuring the uranium, thorium and potassium content in rocks, and the seismic wave velocity can also be calculated in areas without drilling cores.The spatial and temporal distribution of radioactive elements has a great impact on the earth's internal temperature field, sometimes reaching 30%~40% of the surface heat flow history generated by radioactive elements.Therefore, radioactive thermogenic is not only an effective parameter to study the deep physical characteristics such as basin deep thermal conditions and lithosphere thermal structure, but also an important parameter for the recovery of basin thermal history.

In the century survey, the contents of U, Th and K in rock samples are generally determined by using the calculation methods proposed by some scholars, such as the calculation formula proposed by Rybach in 1976:

$$A = 0.01\rho(9.52C_U + 2.56C_{Th} + 3.48C_K)$$

In testing, the buoyancy method is usually used to test the rock sample density. Generally speaking, basalt, tuff, mudstone, and sedimentary detrital rock have a wide range of density fluctuations, which is related to the change in the porosity of such rocks.The content of radioactive

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elements is usually measured by indoor energy spectroscopy.Figure 4 shows the relevant parameters of the gamma-energy spectrometer.

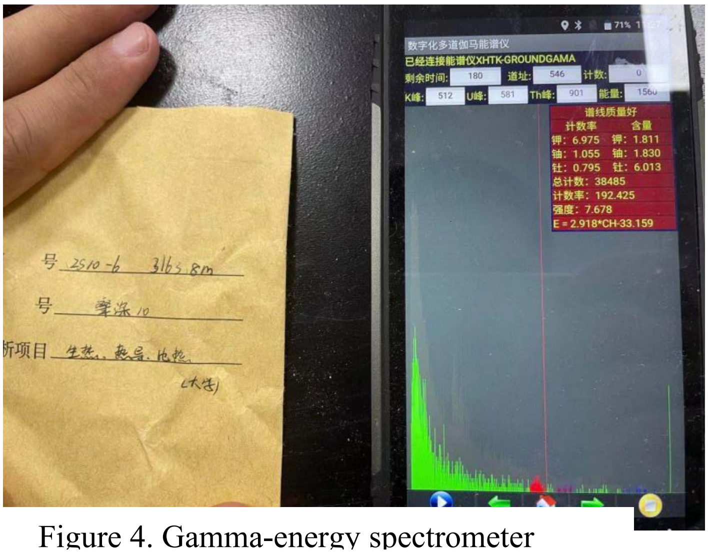

Figure 4. Gamma-energy spectrometer

2.3 Other thermophysical parameters

In addition to the above thermal conductivity and thermogenesis, the rock thermophysical parameters also include density, specific heat capacity, heat capacity and thermal diffusivity.The specific heat capacity of rocks has important significance for the transfer of the heat, and the density are important parameters in the heat history simulation calculation.

3. Restoration of thermal history in ancient temperate Basin

3.1 Geothermal gradient

geothermal gradient, also known as geothermal gradient or geothermal warming rate, especially refers to the change rate of geothermal temperature with depth below the constant temperature zone of the earth. In practice, it is usually expressed by the temperature added value of every 100m or 1km.Under heat conduction conditions, the shallow crustal ground temperature usually shows a linear increase with depth, the ground temperature gradient is not change, but at a larger scale or depth, the ground temperature gradient changes with depth.It tends to decrease with increasing depth, but it does not necessarily decrease linearly, depending on the structure of the lithosphere or crust and its material composition.In the shallow part of the crust, the change of the sediment and the depth of the ground temperature gradient is also controlled by the thermal conductivity of the rock at different depths, under the same surface heat flow.Ground temperature gradient anomaly can be used to study the geological structural characteristics of it, and also plays an important role in studying the distribution of mineral resources, including oil and gas and geothermal resources.

3.2 Earth heat flow

Geothermal flow density is referred to as geothermal flow or heat flow, refers to the heat transmitted from the earth in the form of heat conduction per unit area, unit time to the surface, and then distributed into space.Product of thermal conductivity and vertical geothermal gradient in one dimensional steady state.Heat flow is a comprehensive thermal parameter that more accurately reflects the geothermal field characteristics of a region than other, more fundamental geothermal parameters.Theoretically, it is important to the study of thermal state and activity, thermal structure of crust and upper mantle and its relationship with some geophysical fields. It is a fundamental parameter in the fields of regional thermal condition and crust stability assessment, deep thermal

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prediction, geothermal resource potential and resource evaluation, and oil generation process analysis.

3.3 Factors affecting the ground temperature field of the basin

The geothermal distribution in the basin is controlled and affected by many factors. The heat flow observed on the surface is the result of the superposition or redistribution of the regional background heat flow from the deep in the shallow crust by various factors. Therefore, the influencing factors of the geothermal field in the basin include shallow and deep factors.Generally speaking, the deep factors affecting the ground temperature field of the basin include regional geological structure and deep crust structure.The shallow factors of impression basin mainly include rock thermo-physical properties, groundwater activity, volcanic activity and magmatic activity, topography and precipitation, fracture activity and hot spring distribution

3.4 Ancient temperature standard

Thermal history of sedimentary basin (referred to as heat history) refers to the thermal situation that has appeared in a certain period of geological history, including the basin ground temperature evolution history (or geothermal temperature history) and heat flow evolution history (or referred to as heat flow evolution history).At present, the international methods of basin thermal history recovery can be divided into two categories: one is to restore the thermal history with various ancient temperature scales or geological thermometers, which mainly includes organic matter maturity index and mineral low temperature thermal age (such as fission tracks); the other is to use the thermal dynamics model of the basin evolution to restore the history of thermal history.The ancient temperature scale or geological thermometer, can indicate the temperature experienced during the geological process, but all indicators need to be related to the reaction temperature through the thermal history function of the complex dynamics.

Thermal storage temperature is an indispensable parameter to divide the genetic types of geothermal system and evaluate the potential of geothermal resources. Geochemistry is an important method to understand geothermal fluid system and the most economical and effective means to study underground heat storage in the process of geothermal energy exploration, development and utilization.It is commonly used to study the paleotemperature of the basin using organic matter maturity index, because organic matter maturity is closely related to paleotemperature.The chemical composition, structure and physical properties of organic components change during thermal degradation, and each maturity index is linked by specific chemical dynamics and temperature.Mirror mass reflectance is the most reliable index of organic matter maturity, so it is also the most commonly used index or "thermometer" in the basin paleothermal research.The reconstruction of the basin thermal history can be performed on two different scales, the basin and the lithosphere.At the basin scale, the thermal history is reconstructed using various ancient temperature scales (Hu Shengbiao et al., 1998).At present, the more commonly used ancient temperature standards at home and abroad include mirror mass reflectance, limestone fission tracks, clay minerals, biomarker compounds, fluid package temperature measurement, etc.

The low-temperature thermal dating system is to scale the thermal age of rock samples based on the decay or fission products of radioactive elements in rock minerals in the mineral crystals, that is, to quantitatively reveal the tectonic-thermal evolution history experienced by mountains or sedimentary basins.The low-temperature thermal dating system mainly includes fission path and (U-Th) / He thermal dating two methods.

3.5 Restoration of thermal history in the ancient temperature standard basin

The paleogeological temperature of specific strata at a certain depth in the basin depends on the vertical and lateral changes of the paleothermal flow and the paleoburied depth and the thermophysical properties of rocks related to the paleoburied depth.When the thermophysical

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properties of the rocks in the basin are determined, the ancient geothermal temperature experienced by the sedimentary strata is a function of their buried depth and the femoral heat flow.For the continuous deposition basin, the ancient depth of the formation only needs stripping technology and compaction correction, while for the basin, the maximum depth at the beginning of the erosion and the corresponding paleoheat flow are the unknown amount for inversion.Taking these two unknowns as control variables, by transforming the stratum burial history and thermal history, calculate the variance between the theoretical value and the measured value under this condition, and apply the optimization method to achieve the minimum value of the target function, so as to restore the buried history and thermal history of the basin, which is the basic principle of ancient thermal scale thermal history recovery.

The thermal state of the basin evolution changes dynamically, which directly affects the dynamic process of oil and gas generation, transportation and storage in the basin.The recovery of basin thermal history is not only indispensable to the determination of hydrocarbon stage, organic matter maturity history, primary migration and zone evaluation and trap evaluation, but also an important aspect of the study of basin structure-thermal evolution process.Recovery of thermal history can be performed at the lithosphere and basin scales.On the lithosphere scale, the basin thermal history can be recovered by basin tectonic-thermal evolution; on the basin scale, the thermal history is reconstructed using various ancient temperature scales.There are many kinds of ancient thermal standards, but there are three basic methods to recover thermal history, namely: stochastic inversion method, paleothermal gradient method and ancient thermal flow method.

3.6 Geodynamics Restoration Basin thermal history

Structure-thermal evolution simulation using geokinetic methods is an important means to study sedimentary basins and one of the effective methods to restore basin thermal history.Unlike the ancient temperature scale method, the tectonic-thermal evolution model relies on basin origin types.The structural-thermal evolution simulation of sedimentary basin must be based on the analysis of basin genetic mechanism and the corresponding geo-geophysical model. Structural sedimentation history and thermal flow history constitute its two core research contents.On the theoretical basis, the geodynamic method of tectonic-thermal evolution simulation is based on geological-geophysical model based on basin origin analysis, using numerical method with finite difference or finite element method, focusing on the scale, it studies the regional thermal background of basin evolution

4. Geothermal and oil and gas

Basin thermal history is one of the key factors in the maturation and transformation of organic matter in sedimentary rocks of oil-bearing basin.At present, with the increasing difficulty of oil and gas exploration, the exploration focus gradually turns to the deep ocean and basin, and the research of ancient geotemperature in oil and gas exploration and application has developed rapidly.In China, the study of the ancient geothermal temperature in the sedimentary basin has gradually attracted the attention of the oil and gas exploration department.Many domestic scholars have carried out a lot of research on the thermal history of the vast oil-containing basins in China and achieved a series of results.

At present, a variety of thermal evolution has been gradually formed with basin structure-thermal evolution simulation.However, in general, the study of ancient geotemperature in oil and gas fields is still in a weak link in China. Further research on both the ancient geotemperature research method itself and that applied to basin research is needed.In fact, the present and paleogeothermal temperature of the basin are closely related. The last scene of the evolution process of the basin is the constraint of the basin simulation calculation.Only by obtaining reliable present earth temperature conditions can we further understand the whole thermal history of a basin, the mature history of hydrocarbon source rock and the history of hydrocarbon drainage by other means.

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Reference

[1] Feng Changge, Liu Shaowen, Wang Liangshu, et al., 2009. Tarim Basin present-day geothermal characteristics, geophysical Journal, 52 (11): 2752-2762.

[2] Du Jianguo, Xu Yongchang, Sun Mingliang, 1 helium isotope composition and earth heat flow density in 1998. Chinese mainland.Journal of Geophysics, 41 (4): 494-501.

[3] Hu Shengbiao, Wang Jiyang, 1995. Principles and progress of geothermal system in sedimentary basin.Geothermal front edge, 2 (3-4): 171-179.

[4] Yuan Yusong, Guo Tonglou, Fu Xiaoyue, et al., 2006. Thermal history and Marine hydrocarbon source rock secondary hydrocarbon potential.Modern geology, 20 (2): 283-290.

[5] Zuo Yinhui, Qiu Nansheng, Pang Weiqi, et al., 2010. Study on the evolution characteristics of hydrocarbon source rock stoves in the third section of the Bohai Sea.Journal of Geophysics, 52 (10): 2415-2426.

[6] DICKINSON W R,1974. Plate tectonics and sedimentation.Society of Economic Paleontologists and Mineralogists,Special Publication,22:12-27.

[7] FURLONG K P,CHAPMAN D S,2013.Heat flow,heat generation,and the thermal state of the lithosphere.Annual Review of Earth & Planetary Sciences,41(1):385-410.

[8] HE L J,WANG K L ,XIONG L P, et al.,2001. Heat flow and thermal history of the South China sea.Physics of the Earth and Planetary Interiors,126(3):211-220.

[9] HOOD D,GUTJAHR C C M,1975. Organic metamorphism and the generation of petroleum.AAPG Bulletin,59:986-996.

[10] RYBACH L,BUNTEBARTH G,1982. Relationships between the petrophysical properties density,seismic velocity, heat generation and mineralogical constitution.Earth and Planetary Science Letters,57(2):367-376.

[11] WANGER G,VAN DEN HAUTE P,1992.Fissin-track dating.Amsterdam: Kluwer Academic Publishers.