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The Formation of Overpressure and It's Influence on Oil and Gas in Kuche Foreland Thrust Structural Zone, Tarim Basin, Northwest China

GEOLOGICAL SETTING

Kuche foreland thrust structural zone is located at northern Tarim basin and south side of Tianshan Mountain, NW China. It is adjacent to Tabei uplift. The strata are mainly consisted of Mesozoic group and Cenozoic group. The sedimentary thickness of Mesozoic group generally is 2000-3000m,the maximum thickness is 4000m,it was deposited by sandstones and mudstones of lake, swamp and river facies with coal seam, carbargillite and oil shale at the center and lower site. The sedimentary thickness of Cenozoic group generally is 3000-5000m,the maximum thickness is 8000m,it was deposited by sandstones and mudstones of lake and river facies with two sets of gypsum-mudstone bed and gypsum-salt bed at the center and lower site. There are three sets of assemblages of reservoir and capping bed in Jurassic system, Paleogene system and Neogene system, The coal measures strata in Triassic system and Jurassic system are the main hydrocarbon source rocks.

The tectonic styles in the study area mainly are fold-thrust correlative structures developed in Cenozoic era. They have the characteristics of zoning in north-south orientation and layering in perpendicularity. In plane, there are four zones and two sags which are consisted of monocline structural zone, Kelasu-Yiqikelike structural zones, Baicheng-Yangxia sags and Qiulitage front structural zone from north to south controlled by four basement sliding faults. Controlled by four sets of sliding beds of gypsum-mudstone bed in Jidike formation of Neogene system, gypsum-salt bed in Paleogene system, coal measures strata in Jurassic system and Triassic system and basement detachment layer, the tectonic deformation in perpendicularity obviously had layering which the structures under gypsum-salt bed and above gypsum-salt bed are obviously unsymmetrical.

DISTRIBUTION CHARACTERISTICS

According to acoustic time difference logging and actual drilling surveying data, the coefficient of formation pressure is distributed by EW zoning with reverse S shape in plane(Fig.1).The maximum coefficient of formation pressure lies in several structural settings in the center of the study area. The coefficient of formation pressure in Tubei- Kelasu-Dongqiu-Dina structural zones is more than 2.0 and is reduced to south and to north. The reducing velocity in north is great faster than that in south, most likely because faults developed well and strata uplifted violently before Tianshan mountain, and led to pressure unloaded rapidly. It is approximatively normal pressure system in Tabei uplift, the coefficient of formation pressure is less than 1.3.

The distribution of overpressure is nearly related with gypsum-salt bed and gypsum-mudstone bed in Paleogene system. There is not thick gypsum-salt bed or gypsum-mudstone bed, there scarcely is overpressure. Generally, if the thickness of gypsum-salt bed or gypsum-mudstone bed is over 400-500m,there possibly is overpressure under this place, but not vice versa. Besides huge thick gypsum-salt bed or gypsum-mudstone bed, the distribution of overpressure is also controlled by structural position. The good sealing property of gypsum-salt bed or gypsum-mudstone bed in Paleogene system is the necessary condition for the formation of overpressure.

The overpressure begin to appear at the bottom of Paleogene system(Fig.2) and is the same system both at the bottom of Paleogene system and Cretaceous system. Because of several non-permeable layer, pressure is unevenly changed and has division property within overpressure system of reservoirs. Overpressure is also existed at Jurassic

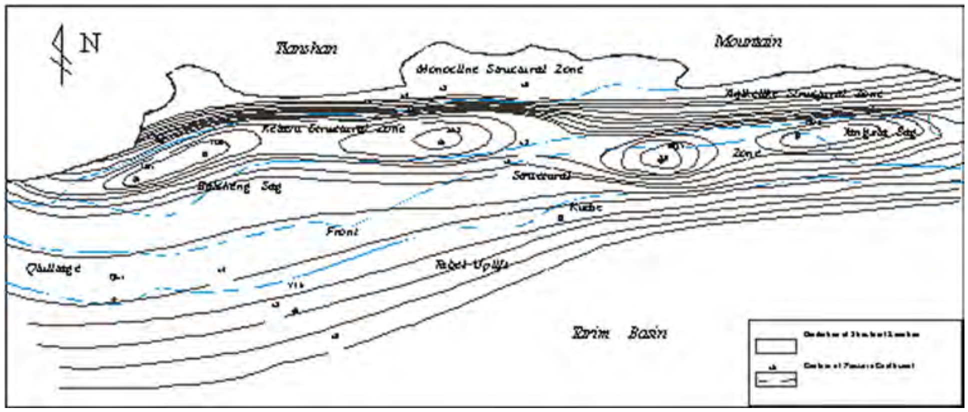

Fig.1 Distribution of coefficient of formation pressure in sandstone reservoirs of Kuche foreland thrust structural zone in Tarim Basin.

system and Triassic system where there is overpressure in Paleogene system and Cretaceous system. According to the actual surveying data of overpressure at several drilling wells in the south of Yiqikelike structural zone, the coefficient of formation pressure in Jurassic system and Triassic system is over 1.9.

GENETIC MECHANISM

There are many kinds of genetic mechanism of overpressure, such as mechanical compaction, hydrothermal pressuring, hydrocarbon generation, dehydration of clays, tectonic movement, temperature change and cementation of the pore space, etc. After denying the possible genetic mechanism of compaction, gas injection after hydrocarbon generation and fluid expand, etc. many geologist thought that tectonic compression and emplacement are the main factors of formation of overpressure in Kuche foreland thrust structural zone. According to geological distribution characteristics of overpressure, study of tectonic stress field and physical simulation experimentation, it is concluded that level tectonic compression in the late of Himalayan Movement is the most likely mechanism for overpressure generation in Kuche foreland thrust structural zone.

The Influence of Tectonic Compression

According to analysis of inclusion, the overpressure was mainly formed in the late stage of Himalayan Movement when the structures were also formed. In term of the analysis of tectonic stress field and strain, the compressional intensity in the study area was stronger and stronger from Yanshan stage, it was reached at peak in the late of Himalayan stage. Using the estimation by rocky memorial information, the mean maximum effective stress is 28.8MPa in the early of Yanshan stage,41.1MPa in the late of Yanshan stage,58.5MPa in the early of Himalayan stage,63.3MPa in the middle of Himalayan stage and 76.4MPa in the late of Himalayan stage. The mean maximum effective stress of Cretaceous reservoirs in the late of Himalayan stage is 80.9MPa.

On the view of regional tectonic position, the overpressure is only distributed at the violent tectonic deformation zone. The pressure system at the Tabei uplift is approximatively normal due to the weak tectonic compression. According to the numerical simulation of tectonic strain field and stress field, the maximum coefficient of formation pressure is distributed at where the strain value and stress value are the biggest. Counting by the actual surveying data of formation pressure and corresponding tectonic stress in several drilling wells, the formation pressures and residual formation pressure are increased along with the maximum tectonic principal stress (Fig.3). Although the surveying data at every drilling well are limited, the distribution law in every drilling well is very clear and completely accordant, it showed the influence of level tectonic compression on the overpressure generation.

Along with more development of thrusting and folding in Himalayan Movement, violent uplift and denudation were also occurred in the study area. According to the analysis by the methods of geological contrast, measuring

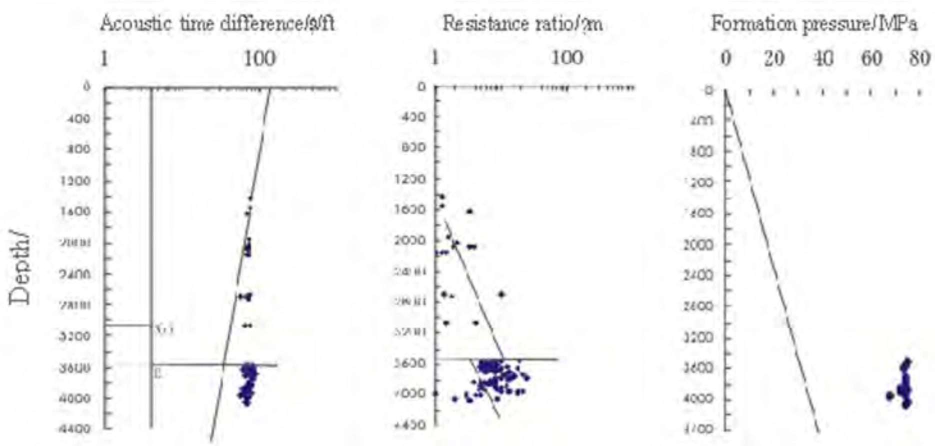

Fig.2 The relation of acoustic time difference, resistance ratio, formation pressure and depth in Kela-2 well, Kelasu structural zone.

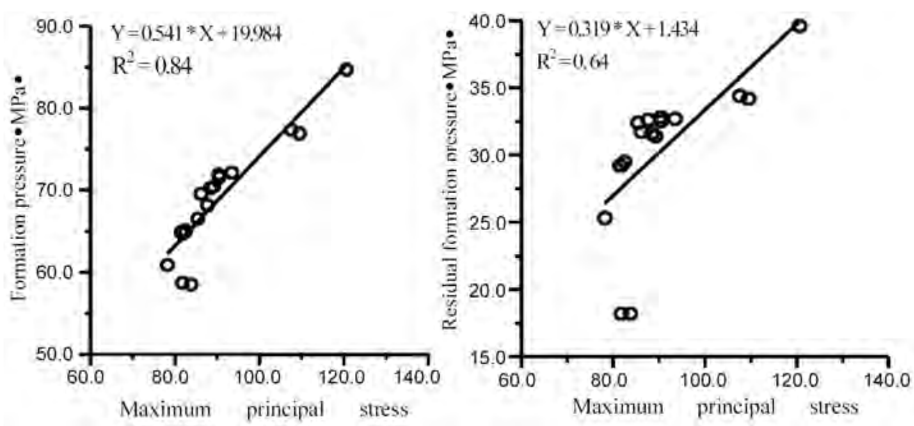

Fig.3 The relation of maximum principal stress and formation pressure, residual formation pressure in Kuche foreland thrust structural zone, Tarim Basin

temperature of inclusion and acoustic time difference, the thickness of denudation in Kuche group of Neogene system is more than 2000m.That is to say, if the formation pressure was not changed after uplift and denudation, the hydrostatic pressure of stratum over 6000m burial depth in geological period could be theoretically turned into present-day overpressure. But if we considered the factor of temperature being reduced, the pressure after uplift and denudation is not high, but static, even apt to lowness by calculation of fluid mechanics equation(Xia Xinyu and Song Yan,2001,2002), So the influence of tectonic emplacement on overpressure generation is little, the dominant factor is level tectonic compression.

Under the strong tectonic compression in the late of Himalayan stage, the rocky pore bulk was diminished. At the same time, due to good sealing property of huge gypsum-salt bed or gypsum-mudstone bed of Paleogene system, fluid could not be drained out. So level tectonic compression stress was partially endured by rocky pore fluid, pore fluid pressure was gone up and formed overpressure of Kuche foreland thrust structural zone. The position closely under the footwall of thrust fault is the intentional drainage point after fluid pressure being increased and the local concentrative position of tectonic stress and shear quantity of heat brought by fault movement in the process of compression and thrust, therefore, the big coefficient of formation pressure is presented closely under the footwall of thrust fault.

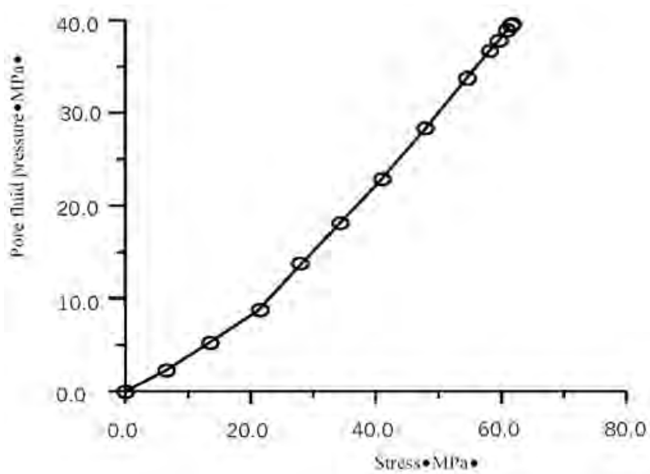

Fig.4 The change curve of rocky pore fluid pressure and compression stress obtained by physical simulation experimentation data

Physical Simulation Experimentation

In order to verify genetic mechanism of overpressure, the physical simulation experimentation has been tested. The simulation experimentation equipment is consisted of sample container with high pressure, axis pressure loading system, confining pressure loading system and measure system. Rocky sample is sandstone of Lower Cretaceous system at the depth of 3825.7m in Kela2 well, which porosity is 12% and permeability is $8\times10^{-3}\mu m^2$. The sample was enclosed by rubber band approximatively to simulate the good sealing effect of gypsum-salt bed or gypsum-mudstone bed of Paleogene system on reservoir. Pressure loaded by confining pressure loading system is 62.7MPa approximatively to simulate confining pressure caused by overlying strata. Pressure loaded by axis pressure loading system is 10.3-67.7MPa approximatively to simulate the influence of tectonic compression stress on pore fluid pressure.

According to simulation experimentation data, the change curve of rocky pore bulk with different axis pressure was obtained at first. It showed that along with axis pressure adding, rocky pore bulk was decreased. The curve could be divided into two sect, the incline ratio of the former sect was bigger than that of the latter sect, showed that the decreasing velocity of rocky pore bulk with stress was faster at the beginning than that in the latter. Then, the change curve of pore fluid pressure with different axis pressure was also obtained. Along with axis pressure adding, rocky pore fluid pressure was increased. The curve could also be divided into two sect, the incline ratio of the latter sect was bigger than that of the former sect, showed that the increasing velocity of pore fluid pressure with stress was faster in the latter than that in the former(Fig.4). At the beginning of tectonic stress action, the stress was mainly endured by rocky grain and turned into rocky skeleton stress. When the tectonic stress was reached to some degree, the stress was mainly endured by pore fluid and turned into pore fluid pressure.

According to study of tectonic stress field, the maximum principal stress in the late of Himalayan stage could be 100-120MPa.Under this stress action, the rocky fluid pressure could be reached to 70-85MPa by the latter curve of pore fluid pressure with stress.That is to say,the coefficient of formation pressure could be 1.8-2.2.It is consistent with the actual coefficient of formation pressure in the study area. Although the simulation condition is not completely consistent with the actual geological condition, specially microcosmic creep deformation mechanism of rock could not be satisfied in the experimentation, this simulation experimentation basically testified the influence of tectonic compression on fluid pressure. The strong tectonic compression was the main forming mechanism of overpressure in Kuche foreland thrust structural zone.

INFLUENCE ON OIL AND GAS FORMATION

The overpressure has quite important effects on formation of oil and gas. It could not only provide driving power for hydrocarbon episodic migrating, but also seal diffusive phase natural gas by concentration, increase reservoir capability and sealing capability of capping bed for oil and gas, make faults have good sealing property. At the same time, it could prevent groundwater, oxygen and bacillus from destroying oil and gas pool. But when overpressure in reservoirs formed before oil and gas injecting, or fluid pressure was higher than that in hydrocarbon source rocks, it was very difficult for oil and gas to migrate to reservoir and accumulate. Furthermore, overpressure could make pressure of gas pools be released and natural gas leak out. These are disadvantages for formation of oil and gas pools.

The large oil and gas pools, specially large gas pools, are closely related with overpressure in Kuche foreland thrust structural zone. The coefficient of formation pressure at oil and gas position was big. Due to desiring for quite good preserving condition for overpressure, the preserving condition was generally good where existed overpressure. It is not lack of oil and gas source in the study area, so it could commonly form large oil and gas pools, specially large gas pools in the tectonic traps where had good preserving condition.

The main reservoir rocks are sandstones of the lower Cretaceous system and the bottom of Paleogene system in the main structural settings of the study area. Oil and gas pools were mainly formed in the late of Kuche group in Neogene period when overpressure generated. The overpressure formed mainly by mechanical compaction before Neogene period was only distributed at middle and lower Jurassic hydrocarbon resource rocks and comparted by mudstone beds in supper Jurassic system and lower Cretaceous system. Under the strong level tectonic compression in the late of Himalaya period, it not only formed faults communicating hydrocarbon source rocks with reservoirs, but also made fluid pressure in reservoirs increase rapidly and formed overpressure layer. Under driving powers of strong tectonic stress and overpressure, oil and gas creating from middle and lower Jurassic hydrocarbon source rocks were vertically and episodically migrated along these faults and accumulated to form oil and gas pools for sealing action by huge gypsum-salt bed in Paleogene system. At the same time, uplift and denudation brought by violent tectonic compression destroyed the balance of fluid pressure in upper stratum, it was also the other main factor for oil and gas migrating. Furthermore, the overpressure in reservoirs strengthened sealing capability of capping bed and prevented groundwater, oxygen and bacillus from destroying oil and gas pools. So oil and gas could be saved to forming large pools. When primary oil and gas pools were destroyed by faults, it could also form secondary pools in the favorable position above gypsum-salt bed in Neogene system.

To sum up, overpressure is the necessary condition for forming large oil and gas pools, specially large oil pools in Kuche foreland thrust structural zone. The time matching of overpressure forming and oil and gas injecting is the key factor to determine the validity of formation of oil and gas pools in overpressure zones.

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