Control Factors of Fluid Migration, Entrapment and their Dynamic Process Simulation in the Central Diapiric Belt, Yinggehai Basin

LI SITIAN, China University of Geosciences; YIN XIULAN, Institute of Geomechanics, CAGS; YANG JIHAI, Institute of China Offshore Oil Nanhai West Corp.

The Cenozoic Yinggehai basin, with huge gas potentiality, is located in the northwestern South China Sea. This basin is characterized by rapid subsidence and large scale expulsion of hot fluid flow, developed a number of commercial gas traps in its center diapiric zone, including DF1-1, LD22-1 and LD8-1 gas fields. The thermal fluid flow activity, mud-fluid diapirism and gas accumulation in the basin are controlled by basin dynamic characteristics, structural stress field and overpressure system.

The geodynamic background of the evolution of Yinggehai basin was directly formed on the Red River fault belt. The basin-fill sequences are mainly Paleocene, Neocene and Quarternary clastic deposits with a thickness up to 16-17km, its subsidence rate was 400m/M.y during Miocene, which is one of the Cenozoic basins with the highest subsidence rate in China. The deep seismic profiles shows two-layer structure of the basin, the lower syn-rifting fault basin and the upper post-rifting down-warped depression with a breakup unconformity in between, indicating that the formation of the basin was mainly related to rifting associated with strike-slip movement. As a result, it has transform-extensional structure characteristics.

The simulating stretching factor is about 2–2.5 in the basin. The Moho discontinuity has been ascertained at the depth of 21-22km according to the gravity inversion and the asthenosphere was upwelling very high. The measured average heat flow value is about 76 mWm⁻², and it is higher at the diapir area after the thermal fluid expulsing upwards.

More than 15 mud-fluid diapiric structures have been found in central zone of the basin which distributed as some rows in NS direction. The dome-like gas traps occurred on the top of the diapirs and some traps occurred at the flanks of the diapirs. The main faults in the diapiric structures are nearly SN trending which were formed in a dextral tenso-shear stress field occurred during late Neogene causing by the strike-slip movement of Red River Fault (Fig.1), which has been testified by the physical simulation (Fig.2).

Because of rapid subsidence, marine shale dominated basin-fill sequence and high geothermal, large scale overpressure compartments were formed. The top surface of the overpressure chamber are only 2000-2500m deep in the diapiric area. En echelon tensional, tenso-shear faults may trigger and control the large-scale hot fluid flow expulsion and dirpirism to form a series of diapirs. After then, the unique local stress field was formed by the rapid lateral and vertical flux of the hot fluids. Hydrofracturing occurred in the low permeability rocks near the top part of the overpressure chamber and then extended to overlaying layers during the diapiric process.

Sediments with overpressure thermal fluids in pores seem to become more flowing and move towards the center of the diapir. In this case, a local compressional structural stress, derived from fluids and mass flow actions, formed a series of compressional fractures and soft deformation at the flanks of the diapirs, while in the dome-like anticline and radial faults occurred over the diapirs.

Moving thermal fluids are capable of transporting with a large amount of heat from the deep part of basin and resulted in the thermal anomalies, which may have caused dilative force and formed a local thermal stress field. The results of fluid migration process simulating shows that shear stress and thermal stress are the maximal in the central fault zone of diapirs, which have become high permeability pathways of overpressure fluid flow migration upwards (Fig.3). Furthermore, the thermal stress field also promoted episodic opening of faults and accelerated
the hydrocarbon-bearing fluid flow upwards. The effect extent of thermal fluids depends on the proportion between thermal stress and tectonic stress.

The changes of stress field and geofluids migration may have been the episodic processes. The episodic openings of fractures seem to be controlled by the episodic wrenching of strick-slip fault in the basement, the episodic accumulating and releasing of the energy from the overpressure chamber. So the entrapment processes in this condition were characterized by the episodic and quick migrating into the traps above the overpressure system. Based on the exploration result of DF1-1 gas field, the gas content is rich in CH₄ in early phase with low-temperature, and rich in CO₂ in late phase with high- temperature. It reveals that the migration pathways, constituted by vertical faults and fractures, gradually extended and punctured to the deep part of the basin.

Therefore, the evolution of the regional structural stress field and the local stress formed by overpressure fluid expulsion may have been the most important factor during gas migrating and accumulating in Yinggehai basin. The process model has been demonstrated and analyzed by the quantitative dynamic simulation.

Fig. 1 Structural framework of the Yinggehai basin A- Geological setting of the Yinggehai basin; B- Distribution of diapirs in Yinggehai basin
Fig2. The result of the physical simulation of the deformation under a dextral strike-slip regime of Yinggehai basin.
Fig3. Distribution of the thermal stress field from the digital simulation of Yinggehai basin (after diapirism) a- $\sigma_{\text{min}}$  b- $\tau_{\text{max}}$