Analysis of reservoir forming conditions of buried hill oil reservoirs in the western slope of Shulu Depression

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Abstract. Development of Shahejie Formation lithologic reservoirs and deep buried hill hydrocarbon reservoirs in the western slope of Shulu Depression. After years of exploration and development practice, the types of buried hill hydrocarbon reservoirs oil and gas reservoirs are diverse, and the hydrocarbon accumulation conditions are not clear, which restricts the pace of oil and gas exploration. Therefore, this paper studies the types and distribution laws of buried hills and the reservoir forming conditions of buried hill hydrocarbon reservoirs. The results show that the west slope of Shulu Depression can be divided into five types: erosion buried hill, fold-erosion buried hill, fault block-erosion buried hill, fold buried hill and fault block buried hill. The buried hill trap is mainly controlled by three factors: unconformity interface, geologic fault and stratigraphic overlap occlusion.

Key words: Shulu Depression; buried hill hydrocarbon reservoir; accumulation conditions; favorable target.

1. Basic geological features
Three sections of Es3, Es2 and Es1 were developed in the Shahejie Formation in the western slope of Shulu Depression. The “special lithology section” consisting of white gypsum, gray paste mudstone, brown mudstone, and shale at the bottom of the sand section[1].The lithologic segment is a regional marker. The medium and upper rocks are light gray fine sandstone, siltstone and fuchsia mudstone. The key strata of this study are the Es2 and Es3. The second member of the Shahe Formation is mainly composed of brown, purple-red mudstone and light-gray fine sandstone; the third member of the Shahe Formation can be further divided into three lithologic sections, the lower part is brown-gray, gray, and gray-white breccia, and the breccia is mainly composed of ash. Rock or dolomite, the cement is gray matter; the middle is brownish gray, gray marl, the local see shale, which is the main oil layer in the depression; the upper part is the dark gray, gray mudstone and light gray fine sandstone interbed[1-3].

Breccia section: The bottom of the sedimentary rock or the top of the bedrock often develops breccia strata of varying thickness. The thickness of the slope and the deep depression area is relatively large, and the thickness is reduced to the high part of the slope. The main lithology is interbed between grey breccia and drab marl. Breccia is composed of limestone and dolomite gravel with occasional sandy debris. The larger gravel diameter is between 5-25cm and 8-12cm in general. The gravel roundness is poor, the near-source sedimentary characteristics are obvious, the inter-gravel structure is tight, the cement is mainly calcite, and the reservoir space is mainly composed of cracks and dissolved pores. The
breccia is mainly developed in the deep concave zone and the slope zone. The area of Jin 100 Well ~ Jin 105 in the west of the area has a maximum thickness of more than 200m. The Jin 403 well in the Taijiazhuang area on the east side of the Shulu depression encountered 536m thick conglomerate. The extensive development of marl and conglomerate sections is a striking feature of this section of the area[4-7].

The upper strata of the buried hill gradually changed new from the deep shoal in the east to the covering strata in the Ningjin dynasty in the west. The cover layer of the slope and the deep shoal is mainly composed of a thick conglomerate body, and the thickness of the west conglomerate is gradually thinned until it disappears. Above the conglomerate body, to the west toward the Ningjin bulge, the cover layer gradually becomes new, followed by the Shahejie Formation, the Dongying Formation, and the Guantao Formation. The Ningjin bulge is mainly covered by the Guantao Formation. Figure 1 shows the development of buried hill formations [8-11].

![Fig. 1 The development of buried hill formations.](image)

### 2. Reservoir forming conditions

The most important feature of buried hill strata is that it undergoes strong tectonic changes and long-term weathering and leaching transformation. In this process, there are many types of buried hill structures with different shapes[7]- [9]. These structures are buried and preserved in the background of the overall sinking, making them the best place for oil and gas gathering.

The buried hill stratum has been transformed into a new fault-depression structure. The uplift area and the depression area are distributed. The uplift area is often a new source area. The deep-soil area often becomes a sedimentary center, long-term transformation and sedimentation, resulting in
acceptance of the deep concave area. In the thick sedimentary strata, the uplifted area is continuously
denuded and almost no sedimentary strata are accepted. The new tectonic changes, combined with
differential settlement and differential gravity, further transform the faulted strata and buried hill strata,
resulting in new faults and new fold structures. These later faulted buried hills and folded hill structures
are also oil and gas accumulations. The best place to become a collector[12-14].

The buried hill trap is mainly controlled by three factors: unconformity, fault and stratum overburden.
The unconformity is the basis for the formation of oil and gas traps, followed by the fault and non-
permeable barrier. Therefore, buried hill reservoirs are associated with regional unconformity.

The buried hill reservoir is mainly the secondary reservoir of the Neozoic. Its formation is closely
related to the fault activity during the oil generation period. During the oil-producing period and the
formation of oil reservoirs, some large faults developed between the oil-producing depression and the
ancient bulge are in a strong active stage. The fault cuts the oil-producing layer and the ancient buried
hill geological body, making it laterally docked. Faults become the main channel for hydrocarbon
migration.

After the formation of the reservoir, this type of fault activity weakens and gradually stops moving,
the fault fracture zone is filled and plugged, the fault property changes from open type to closed type,
and the fault can block oil and gas spillover and become a closed fault, thus becoming the occlusion
boundary of the buried hill reservoir.

Buried hill reservoirs have many different levels of faults, and their effects on oil and gas reservoirs
vary. Near a large number of internal small faults with small fault distances (multi-cluster system
distribution), it is easy to produce dissolution holes and structural dissolution cracks. It becomes an
important oil and gas reservoir space and seepage channel. The main faults in the later reservoirs during
the fault formation period not only trap and block the reservoir, but also divide the reservoir into several
oil-bearing fault blocks, which are also faults in the internal block of the reservoir. For large reservoir
faults distributed between bulges and depressions (an ancient buried hill and oil-producing groove),The
oil-bearing rock is distributed along the groove of the falling plate of the fault,The oil and gas generated
in the new strata migrates and accumulates in the buried hill carbonate or metamorphic reservoir through
the section of this fault. This fault is the main channel for oil and gas lateral migration. At the same time,
the vertical fault distance of the fault is greater than the oil-bearing height of the buried hill reservoir.
After the formation of the reservoir, the fault activity is gradually stopped. Therefore, the late-stage
faults also block the oil and gas spillover and become the trapping condition of the buried hill reservoir.

3. Reservoir and seal assemblage

For buried hill structural traps, having good sealing conditions is the key to oil and gas formation.

Previous studies have suggested that the basal strata include the Archean strata, the Great Wall of
the Middle and Upper Proterozoic, the Jixian system, the Lower Paleozoic Cambrian and Ordovician,
and the Upper Paleozoic Carboniferous-Permian, Among them, the Jixian movement made the area lack
the Qingbaikou system and the Lower Cambrian Junshan Formation. According to the lithology
combination, Three sets of reservoir and seal assemblage can be divided from the Lower Paleozoic to
the Middle Neoproterozoic in the Shulu Depression (As is shown in Figure 2).

The first set of reservoir and seal assemblage:The Ordovician Fengfeng Formation, the Majiagou
Formation and the Fengshan Formation of the Cambrian Upper System act as reservoirs, and the Tertiary
sedimentary layers and dense conglomerate layers above the buried hills serve as caprocks.The shale
and argillaceous limestone with a thickness of 20-30m are developed at the bottom of the Yeli Formation,
and the well logging interpretation is tight.

The second set of reservoir and seal assemblage:The Middle Cambrian Zhangxia Formation is a
reservoir. The lithology is characterized by a large number of braided limestone.TheChangshanYiyishan
Formation, which is covered by the Upper Cambrian, contains a heavier carbonate rock as a cap rock.
Gushan + Changshan Formation: shale, mudstone limestone and argillaceous cloudstoneinterbedded
with a thickness of about 110m. The logging interpretation is mainly a dense layer.
The third set of reservoir and seal assemblage: The Miwushan Formation in the Jixian County of the Middle and Upper Yuan Dynasty is a reservoir. The lithology is a large set of siliceous, algae-containing and sand-bearing dolomite with high local mud content.

The caps of the Xu, Mao, and Yu groups of the Cambrian and the bottom of the Zhangxia group are covered. The majority of the lithology of the Xuzhuang Formation is mud shale, and the Maozhuang Formation and the Shantou Formation are dominated by dolomite, dolomite and shale interbedded layers and dark purple red mudstone. At the bottom of the Zhangxia Formation, a shale and argillaceous limestone interbedded layer with a thickness of about 20 m is developed. The well logging interpretation is mainly a dense layer.

**Fig. 2** Buried hill stratum and reservoir and seal assemblage characteristics

| Boundary system |  | Formation | Drill thickness (m) |
|-----------------|---|-----------|---------------------|
| Jixian system   |  | Wumishan formation Jxw | 555                |
| Middle to upper |  | Tuanzishan formation Cht | 87                 |
| Proterozoic     |  | Chuanlinggou formation Chch | 90             |
| ChenCheng system|  | Changzhougou formation Chc | 245              |
|                 | mid series | Zhangxia formation c,z | 158               |
|                 | higher series | Gushan formation c,g | 55                 |
|                 | lower series | Liangjiashan Formation O,1 | 100        |
|                 | mid series | Fengshan formation c,f | 50                 |
| Paleozoic       |  | Yeli formation O,y |                    |
|                 | mid series | Xiamajiagou formation O,x |                    |
|                 |  | Shangmajiagou formation O,s |                    |
|                 |  | Fengfeng formation O,f |                    |
| Cambrian        |  |                     |                    |
|                 |      |                    |                    |

4. Conclusion
1. The west slope of Shulu Depression can be divided into five types: erosion buried hill, fold-erosion buried hill, fault block-erosion buried hill, fold buried hill and fault block buried hill.
2. The buried hill trap is mainly controlled by three factors: the unconformity surface, the geologic fault and the occlusion of the stratigraphic overlap; The buried hill reservoirs are composed of a wide range of rocks, including carbonate rocks and clastic rocks, as well as igneous rocks and metamorphic rocks. The oil and gas in the buried hill reservoirs are from the hydrocarbon source rocks of the Shahejie Formation and the lower section of the Dongying Formation.

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