Drilling practice Zhongzihao gas exploration well in the thrust belt of the western margin

Hao Wang, Yan Wei *

Drilling & Production Engineering Technology Institute, CNPC Chuanqing Drilling Engineering Company Ltd., Xi'an, Shaanxi, 710018, China

Abstract: The geological structure of Zhong-7 well and Zhong-14 well is the Hengshanpu section of the thrust belt in the western margin of the Ordos Basin, and there have been few construction wells in this area in the past two years. During the construction of the two wells, the formation stability of the entire well section was extremely poor, especially Shiqianfeng. The following strata collapsed seriously and frequently encountered blockages during tripping. During the construction, measures such as optimizing the system, enhancing plugging, improving suppression, wall patching in complex well sections, and fiber cleaning were adopted to obtain valuable experience for the later construction of the Zhongzi gas exploration well in the thrust belt of the western margin.

Keywords: Thrust zone; Gas exploration; Collapse

1. Construction of Zhongzi Well

1.1 Construction of Zhong-7 well

The designed well depth of Zhong-7 well is 3350m, geological structure: Hengshanpu section of thrust belt in the western margin of the Ordos Basin, the completion of drilling the stratum Zhuoshan Formation, the well was opened at 18:00 on March 22nd, surface well depth: 723.48 meters, on April 2nd start at 00:00, the drilling was completed at 00:00 on April 22nd, the drilling depth was 3350 meters, the drilling fluid density was 1.28g/cm^3, the funnel viscosity was 65s, the medium pressure water loss was 3.8mL, and the pH was 9. Among them, on April 16nd, after drilling through the Shihezi Formation, the middle test showed that the well wall was basically stable, and the average well diameter expansion rate was 7.85%. After drilling, the electrical measurement was down to 2501 meters (stone box) and encountered resistance. The instrument was pulled out to drive the well. When the well was drilled, it returned to Shiqianfeng, and the stone box dropped a lot. It took 14.2 days for the double-stone layer to be drilled. On April 28nd, the electrical measurement was completed, and the electrical measurement showed that the diameter of Shiqianfeng and the stone box was seriously enlarged. It was difficult to drill holes in Shiqianfeng and Shihezi before running the casing, and the turntable was severely held back, making it impossible to drill holes.

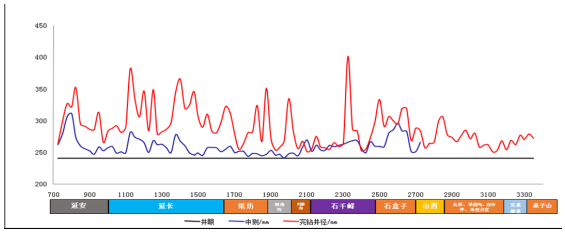

Fig. 1 Diameter diagram of mid-term and completion-drilling electrical logging in Zhong-7 well

* Corresponding author: zjwyan@cnpc.com.cn

Fig. 2 Return drop during well drilling

1.2 Construction of Zhong-14 well

The designed well depth of Zhong-14 well is 3285m. Geological structure: Hengshanpu section of thrust belt in the western margin of the Ordos Basin. The well was opened at 21:00 on August 3nd, and the surface layer was drilled to a depth of 777m. The second was opened at 23:00 on August 9nd, and was drilled to a depth of 3357m (Shanxi) at 4:00 on August 24nd. After 6.5 days of drilling, the drilling fluid density was 1.36g/cm^3, the funnel viscosity was 68s, the medium pressure water loss was 4.2mL, and the pH was 9. During tripping, Shiqianfeng and the stone box encountered serious obstructions. When the pump was turned on, the hole was drawn backwards. When drilling through the well, the pump was held back by the pump, and a large number of double-rock layers fell out, making it impossible to proceed to the next step of construction.

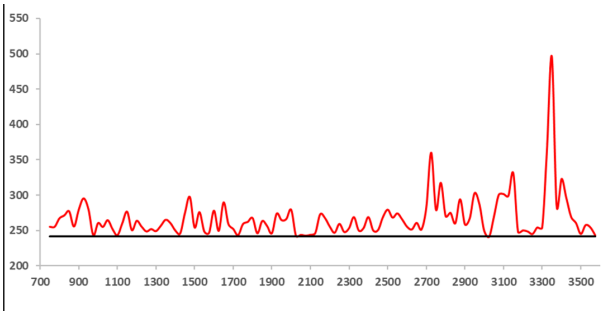

Fig. 3 Completion electrical logging diameter of Zhong-14 well

Fig. 4 Blocks returned from the pass-through of Zhong-14 well

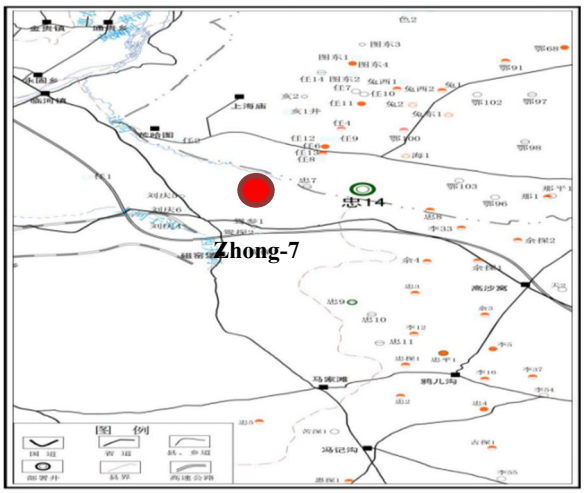

Fig. 5 Geographical location of Zhong-7 and Zhong-14wells

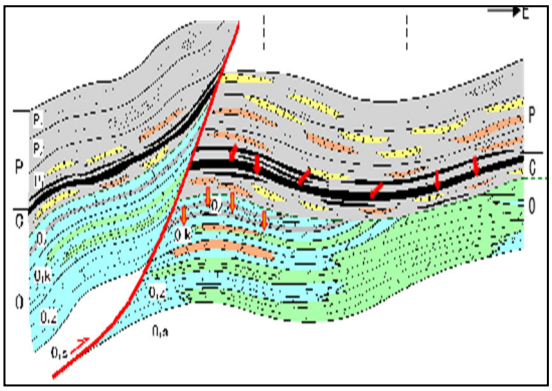

Fig. 6 The structure of the thrust belt in the western margin

2. Stratigraphic characteristics of the thrust belt in the western margin

There are faults in the thrust belt of the western margin from north to south, the stratum is broken[1], and the dip angle is large. Although there is no fault in Zhongzi well, there is in-situ stress concentration, and physical collapse prevention alone cannot balance the formation collapse pressure. The completion density of Zhong-7 well is 1.28 g/cm^3, and the double-stone layer collapses seriously. Zhong-14 well has a density before core-tripping. 1.36g/cm^3, the double stone layer still collapsed.

3. On-site construction drilling fluid technology

3.1 Optimize system performance while improving system inhibition

The compound salt system was used in the construction of the second opening of Zhong-7 well. The lower part of the Yanchang Formation was transferred to the system. After the system was transferred, the compound salt was added by 5-7%. When drilling to the Zhifang Formation, the pulping was serious, and the extended block was lost during the tripping and returning[2]. It shows that the mudstone in the upper stratum has strong dispersive slurrying property, and the system has insufficient inhibition. Adding 5% KCl to the system, the slurrying is obviously improved, and the block loss of the Yanchang Formation is reduced[3].

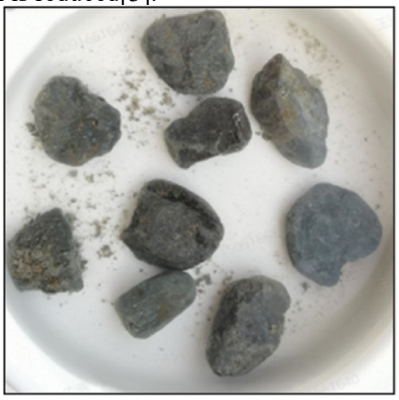

Fig. 7 Blocks of Yanchang Formation in Zhong-7 well are easily dispersed and collapsed after being soaked in water

After the second opening of Zhong-4 well, the system was switched. After the system was switched, 7% KCl was added, and the KCl content of the Yanchang group was increased to 10-12%. The slurry production was relieved to a certain extent, but still could not be completely suppressed. The wellbore stability was improved, and the return sand pattern rules.

Table 1 Performance of the second opening of Zhong-7 and Zhong-14 wells Liujiagou

Parameter	Hashtag	Anding-Zhiluo	Yan'an	Yanchang	Zhifang	Heshanggou	Liujiagou
Density	Zhong-7	1.01	1.02	1.08	1.09	1.12	1.16
	Zhong-14	1.10	1.15	1.20	1.23	1.27	1.30
Viscosity	Zhong-7	33	34	50	68	46	48
	Zhong-14	46	44	48	50	50	55
Dehydration	Zhong-7	18	15	4.4	4.8	5.6	5.2
	Zhong-14	5.2	5.0	5.4	5.0	5.2	4.4

Table 2 Comparison of well diameters of Zhong-7 and Zhong-14 wells in the second opening and Liujiagou

Hashtag	Well section	Formation	Average well diameter expansion rate	Maximum well diameter expansion rate
Zhong-7	750-2700	Erkai-Liujiagou	8.06	23.46
Zhong-14	725-2025	Erkai-Liujiagou	24.91	58.59

From the comparison of Table 1 and Table 2, it can be seen that the transformation of the system in advance, the enhancement of performance, and the enhancement of inhibition can effectively alleviate the collapse of the upper water-sensitive formation[4].

3.2 Using wall solidifying agent to enhance system blocking, improve mud cake and reduce water loss

During the construction of Zhong-7 well, 2% clay slurry was added to the system after the double-stone layer. After Zhong-14 well entered Shiqianfeng, the content of clay slurry was increased to 3%. During the drilling of the well, 1% of wall-reinforcing agent was added to reduce water loss and the quality of mud cake was Better[5], the large drop-out blocks will be gradually reduced when the well is opened in the later stage.

Table 3 Performance comparison before and after the addition of wall cement in Zhong-14 well

	Density (g/cm^3)	Funnel viscosity (s)	Medium pressure water loss (mL)	High temperature and high pressure water loss (mL)
Before wall reinforcement	1.38	136	3.6	14.8
After wall reinforcement	1.38	152	2.7-3.2	13.6

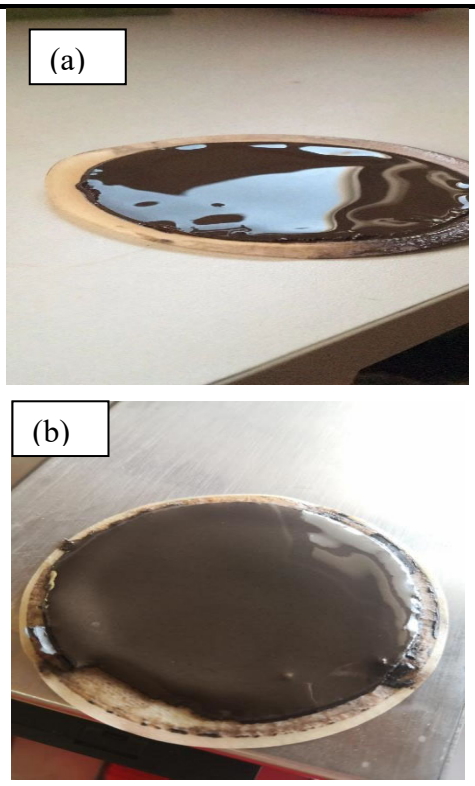

Fig. 8 Medium pressure loss cement cake(a) and high pressure loss of cement cake(b)

3.3 Using thick pulp, heavy pulp, heavy thick pulp, and fiber cleaner to circulate wells during reaming, and carry large droplets in the well

Table 4 Blocks dropped in the well carried by different technical measures in Zhong-14 well

Measure	Performance	Effect
Heavy pulp	On the basis of the original pulp, the density is raised to 1.60-1.65g/cm^3	4 times of cleaning, the first 2 times can bring out some large pieces, and the effect is not obvious in the later period
Thick paste	Viscosity:230-280s	After cleaning 6 times, it can bring out large pieces each time, about 0.5 tons of pieces can be brought out each time, and more pieces can be brought out when used continuously
Heavy and thick pulp	Density:1.55-1.60g/cm^3 Viscosity:160-180s	Use 2 times, the effect of carrying the block is not obvious
Fiber sweeping pulp	Original pulp + 0.13% fiber cleaning agent	Large droplets are not carried out much, but flaky and fine-grained sand is brought out

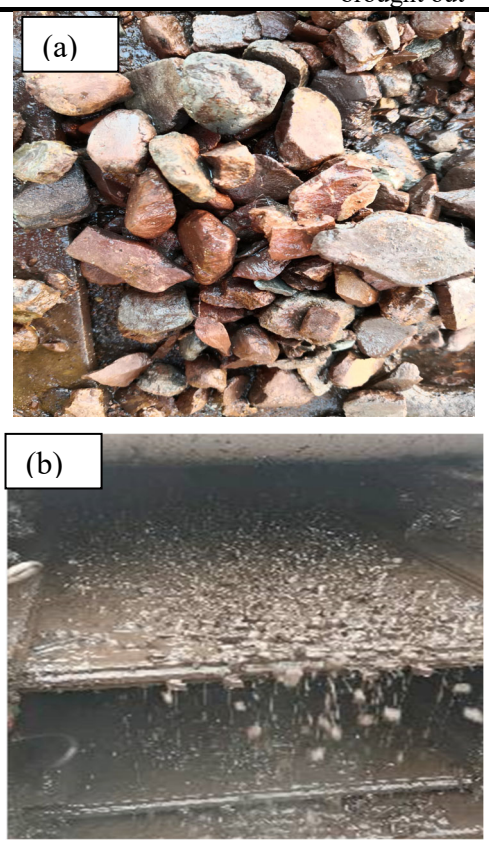

Fig. 9. Heavy pulp belt out of block(a) and thick slurry brings out lumps(b)

3.4 The ductile cement retaining wall in the difficult section of drilling

The electrical survey of Zhong-7 well showed that the double-stone layer collapsed seriously, and the turntable jumped seriously when the well was drilled, and it was difficult to ream the hole[6]. A total of two wall protection cements were applied; the double-stone layer of Zhong-14 well was drilled 6.5 days after drilling, the blockage was serious, and the well was opened. When the turntable jumped frequently, a large number of double-stone layers dropped out, and the cement wall was injected twice on the double-stone layer[7]. The turntable still jumped seriously after the first cement injection was completed and the plug was removed, and the returned cement blocks were high in hardness, large in size, and frequent[8-10]. Hold down the turntable. After the second cement injection, the drill plug is basically normal. After the plug is drilled, it is short and normal, and then the drill is drilled and cored[11, 12].

Table 5 Cement wall protection of Zhong-7 and Zhong-14 wells

Hashtag	Number of wall repairs	Drill plug situation	Wall effect	Remark
Zhong-7	the first time	Plug section 2390-2546m; plug length 156m	The tripping in the wall-filling well section is normal	Continue to scribble, 2597-2636m (stone box) is difficult to scribble, hold down the turntable, lift up and down and encounter resistance, hit cement wall again
	the second time	Plug section 2505-2741m; plug length 236m	Short up and down after eye stroke is normal	After the cement plug is drilled, the lower well section is normal, and the drilling and casing are normal after the well is drilled to the bottom
Zhong-14	the first time	Plug section 2822-3148m; plug length 326m	During the plugging process, the cement block is large, and the turntable is seriously held back	Continue reaming to the bottom of the hole (3357m), the turntable jumps seriously during the reaming process, and the drilling is still abnormal after short tripping, and the cement wall is continued during tripping (3000-3300m)
	the second time	Plug section 3158-3306m; plug length 148m	After the cement plug is swept, the eye-scraping turntable is still throbbing	Continue reaming after the plug is removed, the turntable still jumps, and it is normal after repeated reaming. Before coring, the drill is short tripped for 2 times. After normal, the drilling and coring are normal

Fig. 10 The cement block returned after the first cement injection in Zhong-14 well

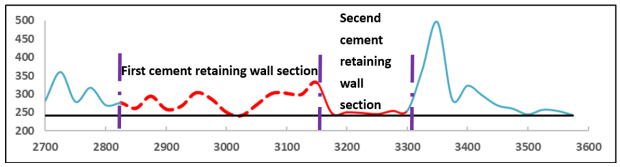

Fig. 11 Shiqianfeng of Zhong-14 well bottom hole diameter

4. Knowledge and advice

There is in-situ stress concentration in the geological structural formation of the thrust belt in the western margin, and the stress release period varies after the borehole is drilled. In this area, the upper strata have good water-sensitivity and pulping ability, and the collapse of the upper strata can be weakened by the measures of turning the system in advance, improving the inhibition, controlling the water loss and increasing the density. Cement solid wall technology has a good effect of stabilizing the well wall for complex well sections, but the wall solidification timing and cement formulation still

need to be further optimized and improved. The wellbore structure in this area still needs to be further optimized. For the current two-opening structure, it can be optimized to three-opening. Before the core is taken, the next layer of technical casing is used to seal the complex formation above the stone box.

References

1. Jing C.Q, Zhang H.L, Hou Y.K. Application of leakage plugging technology in liujiagou layer of exploration well[J]. Chemical Engineering and Equipment, 2021(08): 78-79.
2. Wang S.G. Thinking about the application of geological logging in shale gas exploration wells[J]. Chemical Management, 2018(19): 224.
3. Qin C, Chen X.Y, Cheng Z.Y. Integrated processing technology for salvage and reaming of large-diameter collapses in downholes[J]. Petroleum Drilling Technology, 2020, 48(06): 61-64.
4. Hu Y.K, Ma X, Ma H.Y. Analysis of key technologies for borehole stability in deep exploration wells[J]. Technical Supervision of Petroleum Industry, 2021, 37(10): 20-24.
5. Wang Y.D, Du Z.D, Kang H.Y, et al. Research and application of high-precision 3D exploration technology in the thrust belt in the western margin of the Ordos Basin [C]. Proceedings of the China Petroleum Society 2021 Geophysical Technology Seminar Proceedings., 2021: 156-159.
6. He D.F, Shao D.B, Kai B, et al. Structural style and trap distribution in the Majiatan area on the western margin of the Ordos Basin[J]. Journal of the Earth, 2019, 40(01): 219-235.
7. Miao S.J, Yao L, Li B.X. Geology-geophysical characteristics and geothermal exploration of the Pingliang section of the thrust belt in the western margin of the Ordos Basin[J]. Geology of Gansu, 2017, 26(04): 51-56.
8. Zhang Y.L, Guo Y.R, Gao J.R, et al. Analysis of Ordovician paleo-tectonic features and exploration prospects in the thrust belt in the western margin of the Ordos Basin[C]. Collection of abstracts of the 8th China Petroleum System and Oil and Gas Reservoir Academic Conference., 2015: 113.
9. Luo Q. Characteristics of the faults in the thrust belt in the Majiatan area on the western margin of the Ordos Basin and its reservoir-controlling model[J]. Journal of the Earth, 2008(05): 619-627.
10. Wang Z.C, Wang Y.X. Majiatan detachment thrust structure in the western margin of Ordos[J]. Petroleum and Natural Gas Geology, 1996(03): 221-225.
11. Wu H.T, Xu X, Wang L, et al. Mud purification technology on construction site[J]. Construction Technology, 2020, 49(S1): 1690-1691.
12. Jia X.P. Practice and understanding of drilling fluid construction in X-P1 well[J]. Western Prospecting Engineering, 2020, 32(06): 36-38+42.