IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 3, Issue 6 Ver. I (Nov. - Dec. 2015), PP 28-32
www.iosrjournals.org

Reservoir Characteristics of Complex TightGas Reservoir for Second Member of YingchengFormation, Yingtai Area

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Abstract: *Second Member of Yingcheng Formation reservoir has strong anisotropy in Yingtai area. It is the complex tight gas reservoir with low porosity and low permeability, and the reservoir characteristics control potential distribution of target formation in study area and making development plans. Thus, this article carries out a research on sedimentary characteristics, lithofacies characteristics, lithological characteristics, characteristics of physical properties, distribution characteristicsof reservoir, and distribution characteristics of gas reservoir. Research results of Second Member of Yingcheng Formation indicate that: distribution of gas formation is controlled by the reservoir development level and physical properties, the higher level reservoir develops, the thicker thickness of gas reservoir is. The better reservoir physical properties are, the better result gas test has, and the higher production gas test has. On the vertical direction, distribution characteristics of nature gas is: gas formation buries deep, gas well section is long, and the thickness of gas formation has great change on the cross direction, distribution is not controlled by the high or low structure.*

Keywords: *Tight Gas Reservoir,Low Permeability Reservoir, Reservoir Characteristics, Sedimentary Pyroclastic Rock,Second Member of Yingcheng Formation*

I. Introduction

Deep formation of SongliaoBasin isabundant in natural gas. Proved natural gas reservevolume has been verified more than $3\times10^{11}m^3$ so far, showing that deep formation of Songliao Basin has tremendous exploration prospect and well development potential [1-4]. Second Member of Yingcheng formation, Yingtai area is located in Longshensecond and third well block, Yingtai area, southern Songliao Basin. Type of gas reservoir is the lithology gas reservoir, lithology and lithofacieshave great change;average porosity is 7%, and the average permeability is $0.05\times10^{-3}\mu m^2$; pore structure and the relation of porosity-permeability are both complex, all these indicate that Second Member of YingchengFormation contains complex tight gas reservoir.

After fracturing and gas-testing for the target formation in study area, from the geological characteristics of wells which have been already obtained industrial gas flow, it shows that gas distribution is related to the reservoir geological characteristics such as lithology, lithofacies, physical properties. Thus, study of the reservoir geological characteristic for Second Member of YingchengFormation, Yingtai area can lay a foundation for the further study of the target formation'spotential distribution and making development plans.

II. Sedimentary Characteristics

Deep formation of southern Songliao Basin contains Quantou Formation and the formations below it, mainly are Upper Jurassic – Lower Cretaceous structural layers and Lower Cretaceous depression structural layers [5-9]. According to the drilling data, deep formation of Yingtai rift develops from the bottom to top: Huoshiling Formation of Upper Jurassic, Shahezi Formation, Yingcheng Formation (First – Third Member), Denglouku Formation, Quantou Formation (First andSecond Member) of Lower Cretaceous. Natural gas mainly distributed in First and Second Member of Yingcheng Formation, Denglouku Formation, Firstand Second Member ofQuantou Formation (Table 1).

Table 1 Stratigraphic tablefor deep formation of Yingtai rift

Stratigraphic Position				Stratigraphic PositionCode	Formation Thickness	Description of Lithology and Lithofacies
System	Series	Formation	Member		meter	
Cretaceous (K)	Lower Cretaceous (K_1)	Quantou (q)	Second	K_1q^2	240-258	Meandering river facies, interbedded in unequal thick consisting ofsiltite, fine sandstone and mudstone.
			First	K_1q^1	160-620	Braided river, meandering river, alluvial fan. Interbedded in unequal thick consisting of glutenite, siltite, fine sandstone and mudstone.

		Denglouku (d)		K_1d	150-550	Braided river (delta), alluvial fan, conglomerate at the bottom, interbedded in unequal thick consisting of variegated glutenite, mauve mudstone and grey mudstone at the middle and top.
		Yingchen (yc)	Second	K_1yc^2	350-980	Lake facies, fan delta facies with volcanic facies,， interbedded in unequal thick consisting of heavy mudstone layer and sedimentary tuff, diorite and andesitic porphyrite in some parts.
			First	K_1yc^1	200-800	Volcanic facies, rhyolite and rhyolitic breccia for the most part, neutral – basicity andesite and basalt.
		Shahezi (sh)		K_1sh	300-500	Deep lake – semi deep lake facies, dark mudstone for the most part with thin siltite, fine sandstone layer.
Upper Jurassic (J_3)		Huoshiling (hs)		J_3hs		Volcanic facies, andesitic tuff for the most part.
Carboniferous – Permian (C-P)				C-P		No drilling indicates.
Anti-Sinian (Anz)				Anz		

During mid-term Yingcheng Formation sedimentation as Second Member of Yingcheng Formation, lake transgression happened in a large area with fractured volcanic eruption and shallow formation invasion in some parts [10-13]. Drilling data of Longshen first block indicates that the remaining thickness of Second Member of Yingcheng Formation is 0–500m, and the main lithology is dark mudstone, diorite and andesitic porphyrite. Drilling data of Longshen second block indicates that the remaining thickness of Second Member of Yingcheng Formation is 100–850m, and the main lithology is dark mudstone, sedimentary tuff, and sedimentary volcanic breccia.

III. Reservoir Characteristics

3.1 LithofaciesCharacteristics

Sedimentary characteristics of Second Member of Yingcheng Formation is: lake facies with strong volcanic activity around Longshen third well block.With continuous source supply, it forms the typical volcanogenic sedimentation construction. Sedimentation of this block is volcanogenic sedimentary facies in the transition between volcanic facies and detrital sedimentation facies of terrigenous origin. It is controlled by both evolution of lakes basin and volcanic eruption, and it has the sequence characteristics of volcano – sedimentation [14-17].

Through analysis of the single well samples, core facies and logging facies, Second Member of Yingcheng Formation mainly develops volcanic facies, volcanic – sedimentary facies. Volcanic facies is divided into explosive facies, eruption facies and volcanic vent facies. From the source side, volcanic – sedimentary facies is divided into volcaniclastic rock subfacies with extraclast and rehandlingvolcaniclastic rock subfacies. From the sedimentary characteristics side, it is further divided into alluvial facies, fan delta, braided river delta, paludal facies, shore-shallow lakefacies and deeper lake facies.

3.2 ReservoirDistribution Characteristics

Formation thickness of Second Member of Yingcheng Formationin Longshen second and third well block is 100m – 1100m, the deepest formation is mainly distributed in Longshen306 – Longshen 206 well block. Interpreted reservoir thickness of single well is 30m – 90m in general, and the deepestone is Longshen 306 well which is 148m thick.

Sandstone reservoir distribution of Second Member of Yingcheng Formation at the top: Longshen third well block drilling indicates that there are 11 wells in the sandstone formation of upper Second Member of Yingcheng Formation, formation thickness of single well is 120m – 300m, interpreted reservoir thickness is 4m – 80m, average thickness of single well is 42m, reservoir – formation ratio is 2%–39%. Predicted reservoir thickness is 0m – 80m, it exhibits a bolt in shape extending in a north-south direction along controlling-depression fault extension direction on the plane. Distribution characteristics is thick in the west and thin in the east as a whole.

Sandstone reservoir distribution of Second Member of Yingcheng Formation at the middle: drilling indicates that there are 10 wells in the sandstone formation of middle Second Member of Yingcheng Formation, formation thickness of single well is 196m – 303m, interpreted reservoir thickness is 9m – 48m, average thickness of single well is 26m, reservoir – formation ratio is 3%–21%. Predicted reservoir thickness is 0–60m, it exhibits a bolt in shape extending in a north-south direction along controlling-depression fault extension direction on the plane. Distribution characteristics is thick in the west and thin in the east as a whole.

Sandstone reservoir distribution of Second Member of Yingcheng Formation at the bottom: drilling indicates that there are 10 wells in the sandstone formation of lower Second Member of Yingcheng Formation, formation thickness of single well is 14m – 314m, interpreted reservoir thickness is 5m – 32m, average thickness of single well is 26m, reservoir – formation ratio is 3%–21%. Predicted reservoir thickness is 0m – 50m, distribution characteristics is thick in the west and thin in the east on the plane.

Based on the analysis above, Second Member of Yingcheng Formation reservoir is controlled by the fault extension direction on the plane, and the thickness has great change, superposed and interconnected on the vertical direction. All these provide reservoir conditions to the regionallycontinuous accumulation.

3.3 LithologicalCharacteristics

Main lithology of Second Member of Yingcheng Formation is sedimentary pyroclastic rock, then is pyroclastic rock. Sedimentary pyroclastic rock accounts for 79%, and the pyroclastic rock accounts for 21%. Characteristics of sedimentary pyroclastic rock is:for the rock mineral composition,rock fragment content is 50%–80%, quartz and feldspar content is 20%–40%. Volcanic detritus accounts for over 90%, rock fragment of sedimentary rock and metamorphic rock accounts for 10% below.

According to the rock texture and genesis, lithology of Second Member of Yingcheng Formation can be divided into sedimentary tuff, sedimentary breccia crystal detritus tuff, sedimentary volcanic breccia, tuff and volcanic breccia.

Based on the lithological characteristics of Second Member of Yingcheng Formation, it is used to compare scale between conventional logging response characteristics, imaging characteristics andcoring data, slice data. The result is obvious where FMI imaging is used to understand macrostructure, and microstructure can be identified by logging and ECS element logging. With grain size from coarse to fine, the clay content (Vcl) increases, resistivity decreases, density increases, and the acoustic time response increases. Thus, it can identify the lithology of Second Member of Yingcheng Formation by using clay content – resistivity crossplot. It can identify lithology into 3 categories and 11 types by using FMI imaging logging, conventional logging and ECS element logging.

3.4 Characteristics of PhysicalProperties

Based on the physical properties analysis of 144 sedimentary volcaniclastic rock samples of Second Member of Yingcheng Formation in Longshen second and third well block, maximum porosity is 19%, porosity is 5%–9% in general, and the average porosity is 7%. Maximum permeability is $1\times10^{-3}\mu m^2$, average permeability is $0.05\times10^{-3}\mu m^2$. Logging interpreted porosity is 5%–12%, and the average porosity is 8%(Figure1, Figure2). Research and statistics results indicate that: as a special reservoir type between volcanic rock and clastic rock，sedimentary volcaniclastic rock has the characteristic of great change physical properties and strong anisotropy. Reservoir physical properties is affected a little by the buried depth, and it is related to the corrosion, devitrification and strong compaction resistance ability of the detritus grain. In general, the coarser grain of the rock, the better physical properties of the reservoir.Physical properties of sedimentary volcaniclastic rock is better than the one of sedimentary tuff. Density of sedimentary volcaniclastic rock is $2.40g/cm^3$–$2.50g/cm^3$, porosity is 7.0%–12.0%. Density of sedimentary tuff is $2.46g/cm^3$–$2.55g/cm^3$, porosity is 4.0%–8.0%. According to the classification standard of reservoir physical properties, Second Member of Yingcheng Formation reservoir in Yingtai area is the low porosity and permeability reservoir.

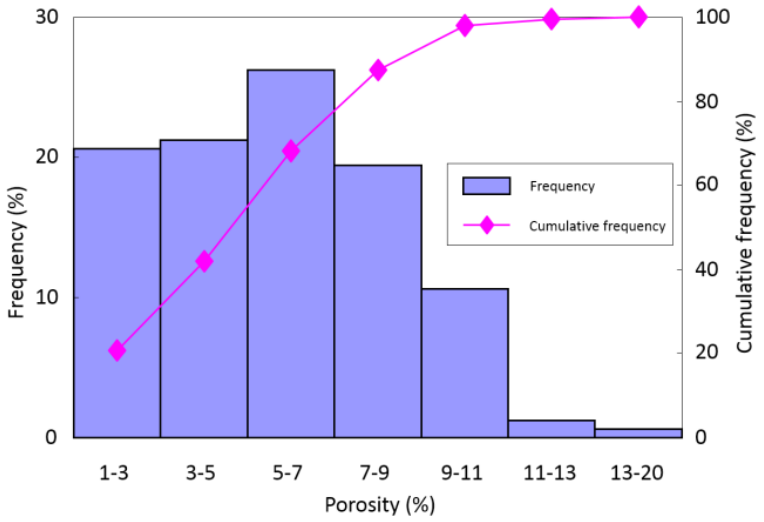

Figure 1 Porosity distribution histogram of Second Member of Yingcheng Formation

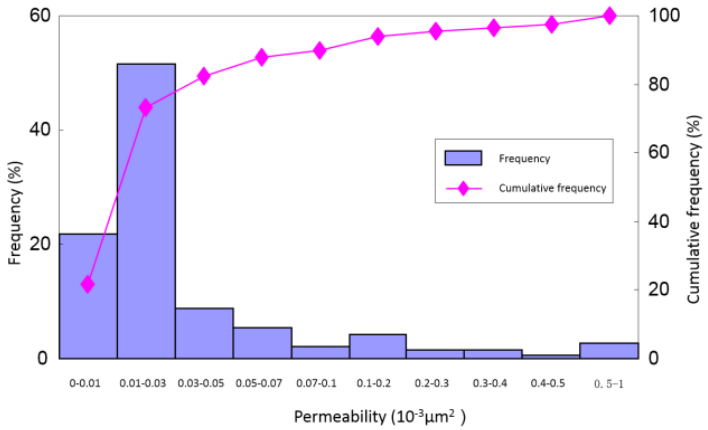

Figure 2 Permeability distribution histogram of Second Member of Yingcheng Formation

IV. DistributionCharacteristicsof Gas Reservoir

Drilling of Longshen third well block indicates that there are 11 gas wells of Second Member of Yingcheng Formation. On the vertical direction, gas formation buries deep, gas well section is long, and the thickness of gas formation has great change on the cross direction.Distribution is not controlled by the high or low structure. The specific contentsare as follows:

1. Distribution of gas formation is not controlled by the high or low structure.Drilling indicates that the lower gas formation at high structure buries higher than the upper gas formation at low structure. Thickness of gas well at high structure is the same as the one of gas well at low structure.
2. Distribution of gas formation is controlled by the reservoir development level and physical properties. The higher level reservoir develops, the thicker thickness of gas reservoir is. The better reservoir physical properties are, the better result gas test has, and the higher production gas test has.
3. Distribution of gas formation is controlled by the sedimentary formation. The thicker formation thickness is, the longer gas well section is, and the thicker accumulative reservoir thickness is. Controlled by the west Wukeshufault, the thickness of west sedimentary formation is thicker than the one of east sedimentary formation. Based on the reservoir predicted result, at the north side of the depression – control fault, the thickness of formation is 800m – 1000m, and the reservoir develops; at the depression – control fault, the thickness of the formation and gas formation thin rapidly, some reservoir contact to the fault directly; around the north boundary of the fault, the thickness of the formation is 100m – 300m, and the thickness of the gas formation thin gradually. Study of the natural gas reservoir indicates that, Second Member of Yingcheng Formation is the self-generating and self-preserving reservoir.Source rock of deep lake facies generate oil and gas through high pressure hydrocarbon expulsion, then they migrate to the reservoir nearby directly, and they accumulate and form reservoir in the lithological trap.Connectivity of Second Member of Yingcheng Formation reservoir is not very well, and every single layer can form lithological trap.Thus,Second Member of Yingcheng Formation is a superposed and interconnected lithological trap group on the plane composed by many lithological traps.

V. Conclusions

1. Second Member of Yingcheng Formation mainly develops volcanic facies, volcanic – sedimentary facies. From the sedimentary characteristics side, it is further divided into alluvial facies, fan delta, braided river delta, paludal facies, shore-shallow lake facies and deeper lake facies.
2. Second Member of Yingcheng Formation reservoir is controlled by the fault extension direction on the plane, and the thickness has great change, superposed and interconnected on the vertical direction. All these provide reservoir conditions to the regionally continuous accumulation.
3. Lithology of Second Member of Yingcheng Formation is: Sedimentary pyroclastic rock accounts for 79%, and the pyroclastic rock accounts for 21%. It can identify lithology into 3 categories and 11 types by using FMI imaging logging, conventional logging and ECS element logging.
4. Based on the physical properties analysis of 144 sedimentary volcaniclastic rock samples of Second Member of Yingcheng Formation in Longshen second and third well block, maximum porosity is 19%, porosity is 5%–9% in general, and the average porosity is 7%. Maximum permeability is $1\times10^{-3}\mu m^2$, and the average permeability is $0.05\times10^{-3}\mu m^2$. Logging interpreted porosity is 5%–12%, and the average porosity is 8%. According to the classification standard of reservoir physical properties, Second Member of Yingcheng

Formation reservoir in Yingtai area is the low porosity and permeability reservoir.

5. On the vertical direction, distribution characteristics of nature gas is: gas formation buries deep, gas well section is long, and the thickness of gas formation has great change on the cross direction.Distribution is not controlled by the high or low structure.

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