# Study on tight reservoir law and prediction of favorable areas-Take Wangjiawan well block Wang 107 as an example

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**Abstract**—When the development of oil field continues, the production efficiency of the whole oil well will decline significantly. It is of importance to analyze the geological factors related to the reservoir storage law in order to re recognize the current status of the oil well and extract more resources from the oil well. This paper expounds that at the stage of oilfield development, the research on reservoir characteristics, reservoir sedimentary facies and reservoir characteristics and laws are discussed in depth and comprehensively, and the prediction of favorable areas of the oilfield is studied, which has brought corresponding references to oilfield staff. For the late stage of oilfield development, we should carry out fine geological research, determine the geological type, provide the best data base for improving the development plan of the reservoir, and carry out scientific analysis and research to improve the productivity of the late stage of reservoir development, so as to achieve the expected production efficiency.

## 1. Introduction

### 1.1 Research background and significance

In Wangjiawan, Xiwang 107 well area is the site of a new edge expansion exploration in 2018 - the study area. Two main oil layers, Chang 4+5 and Chang $6_1^1$, cover a total of 31 $km^2$. The daily oil production of well Wang 107 is 3.5t for 6 layers, and the daily oil production of test layer is 611 small layers, with 1.72t a day of production.Currently, 119 production wells, 5 exploration wells, and 21 water injection wells exist in the region. For the first time, Chang 6 oil-bearing series have been discovered in this area, yet no systematic research has been conducted on it. At present, there are several key problems that need to be solved urgently as follows:

(1) A profounder comprehension of sedimentary characteristics and reservoir features must be attained.

Research findings demonstrate a dearth of exploration into sedimentation, the sedimentary facies diagram is inadequate to demonstrate the development features and physical property regulations of sand bodies, and the research on reservoir characteristics and oil and gas enrichment laws is comparatively feeble, making it hard to direct the next exploration deployment based on these findings.

(2) At present, the study region has low reserves and a rapid decline in production.

The core of the above two dilemmas lies in the unclear distribution law of high-quality reservoirs.It is essential to classify and assess reservoirs, in conjunction with the examination, testing, and logging of data, to make clear the physical property distribution characteristics of various reservoirs and then create a development plan.

### 1.2 Research objectives and main research contents

#### *1.2.1 Research objectives*

(1) The exploration area of Wang 107 in Wangjiawan, which is the target layer of Chang 4+5 and Chang 6 of the well, is determined by reserve estimation and reservoir evaluation, based on the layout of sand bodies, sedimentary facies, and microfacies in the plane.

(2) A comprehensive evaluation of the development mode and water injection effect, based on the well logging interpretation model of oil and water wells locating in the study field, has been conducted, and reasonable proposals for the alteration of the upcoming development plan have been proposed.

#### *1.2.2 research contents*

（1）The regional stratigraphic and structural research results, in combination with logging, sedimentary data, were used to analyze the control of structures on oil and gas. This was done by correlating the marker beds in detail, stratigraphic division and correlation of the Chang 4+5 and Chang 6 layers in the study field were conducted, and the structural morphology of the Chang

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4+5 and Chang 611 sublayers was studied.

（2）Establishing a division standard for sedimentary facies and microfacies, and separating single well facies; analyzing the distribution characteristics of sedimentary facies, and sketching the section and plan of sedimentary microfacies of small layers Chang 4+5, Chang $6_1^1$ - these are the steps to take.

（3）A mathematical model is devised to systematically assess the features of oil and gas distribution, control factors, reservoir types, and driving modes.

（4）The study field's structural characteristics, sand body distribution and reservoir characteristics have revealed favorable oil and gas enrichment blocks.

*1.2.3 technology roadmap*

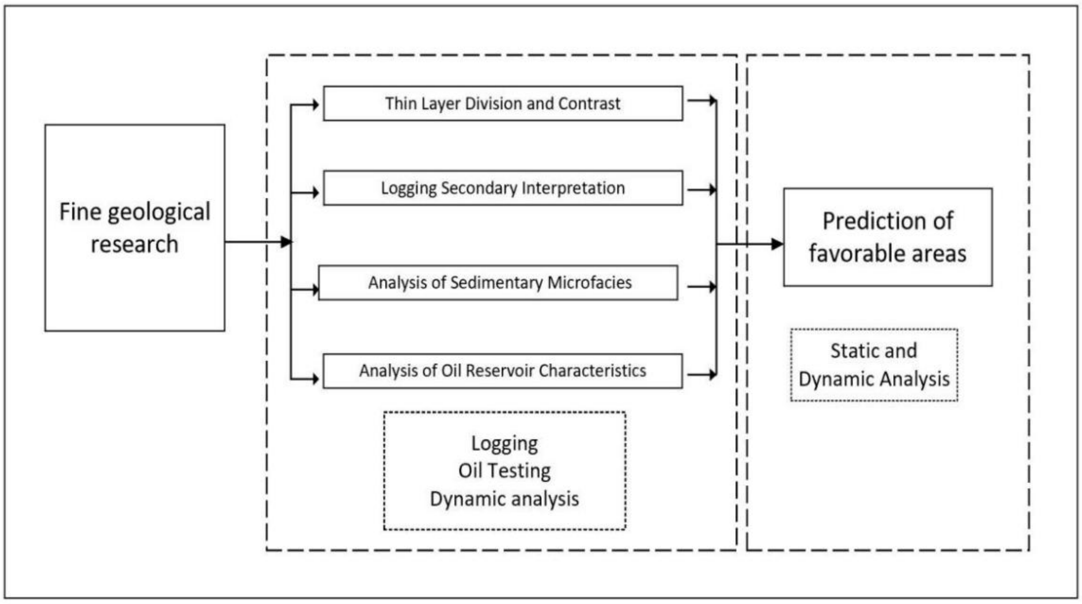


Fig. 1 Technical route flow path

## 2. Geological overview and geological characteristics

### 2.1 regional tectonic background

Beginning at Yinshan in the north, Ordos Basin progresses to Qinling in the south, terminates at Luliang Mountain in the East, and culminates in the Tengger Desert in the West. This sedimentary basin, which ranks as second largest in China, encompasses a size of approximately 37×104km$^2$, and is comprised of Shaanxi, Gansu, Ningxia, Mongolia, and Shanxi provinces.Surrounded by mountains, the basin of Meso Cenozoic fault basins, which includes Hetao, Yinchuan, BAYANHOT, Liupanshan, Weihe, stretches from south to north, 400km wide from east to west, and encompasses 25×104km$^2$ in total. The Great Wall, arid desert grasslands in the north, and semi-arid Loess Plateau Area in the south, crisscross valleys, and complex terrain make up the basin.

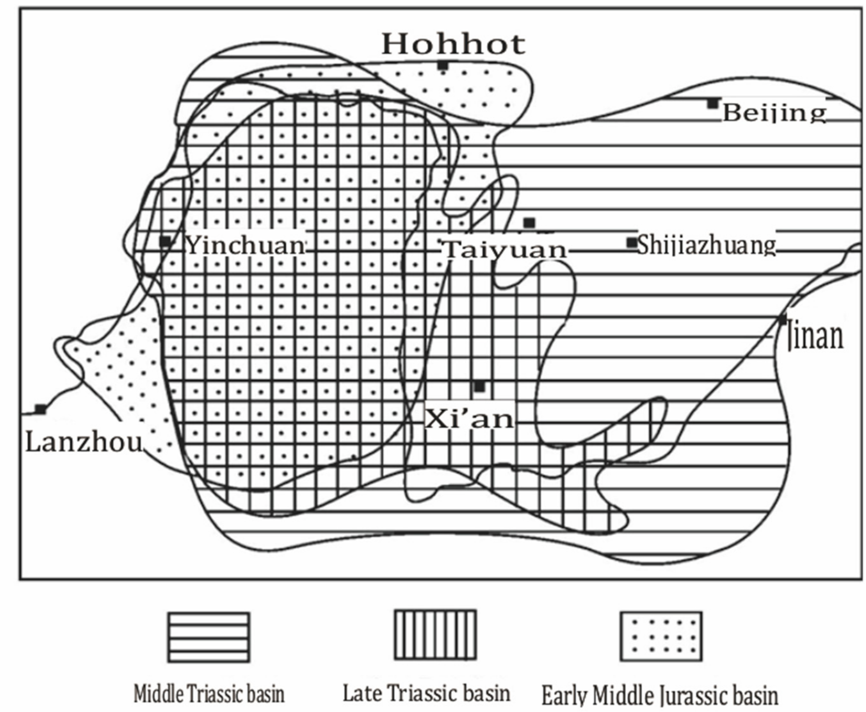


Fig. 2 evolution superposition diagram of middle Late Triassic and early Jurassic in Ordos Basin

## 2.2 types and features of sedimentary facies

The study area's Chang 4+5 and Chang 6 oil-bearing formations, as revealed by the regional geological survey and facies marker analysis of Wangjiawan wang107, are part of the delta sedimentary system. Delta deposits are typically parted into the following three facies zones: delta plain, delta front, and pre Delta. An examination of lithofacies and logging in the research region has led to the conclusion that the Chang 4+5 oil layer of the upper Triassic Yanchang Formation is mainly composed of delta plain deposits, while the Chang 6 mainly delta front deposits.

Classification of sedimentary facies types of Chang 4+5 and Chang 6 oil layers in the study area is presented in Table 2-1.

Table.1 Classification of Sedimentary Facies in the Chang 4+5 and Chang 6 Oil Layer Formations in the Study Area

| mutually | Subfacies | Microfacies | Production horizon |
|---|---|---|---|
| three horn continent | Delta plain | Water distributary channel<br>Inter distributary depression<br>Natural levee on water<br>Water crevasse fan | Length 4+5 |
| | Delta front | Underwater distributary channel<br>Distributary Bay<br>Underwater natural dike<br>Underwater crevasse fan | Length 6 |

## 2.3 reservoir characteristics

The Wangjiawan well block Wang 107 is a reservoir with low permeability, low abundance, low production, and high water cut, and its oil-water distribution is intricate. Therefore, to understand the oil enrichment law of the oilfield, there is a need to first study the oil-water properties and their change law.

In this area, the Chang 4+5 and Chang 6 reservoirs are of lithologic origin, and the oil and gas distribution mainly depends onthe lithology and physical features of the reservoir. Generally, the enrichment area of these reservoirs is the distribution area existing high-quality reservoirs, which are mainly formed in delta plain water distributary channel deposits and channel side edges, which are spread out along the plane and intersect NE-SW. Both sides of the sand body and the updip direction are interbedded with mudstone and siltstone deposited in the distributary depression, forming the lithologic barrier of Chang 4+5 and Chang 6 reservoirs.

In this region, the Chang 6 reservoir is a typical example of an elastic solution gas drive lithologic reservoir, due to its inadequate physical characteristics, the lack of a clear oil-water boundary, the combination of oil and water storage, the absence of an obvious oil-water interface, and the absence of both edge and bottom water.

## 3. Chapter 3 logging interpretation model and reserve estimation

### 3.1 porosity logging interpretation model research

The correct calculation of reservoir parameters is very important for logging interpretation. When the reservoir parameters accurately reflect the formation conditions, they can precisely pinpoint the reservoir fluid properties, furnish technical parameters for oil testing and fracturing, and offer technical assistance during the explotary development process of the oilfield.

(1) Porosity interpretation model

Geologists are particularly concerned with porosity, which is a critical factor in assessing a reservoir a reservoir's quality, and is a key geological parameter. When water and oil are completely contained in the local formation, the porosity of the formation can be truly reflected by acoustic logging curve, density logging curve and neutron logging curve.Consequently, a single porosity logging curve is generally capable of precisely ascertaining the porosity of formation.

Porosity analysis of Chang 4+5 formation shows a close correlation between acoustic wave and reservoir porosity (Fig.The relational expression is thus:

Por=0.3467× Ac-70.616 r=0.9328

A correlation between log sonic transit time and the core porosity analysis is demonstrated by the porosity analysis of Chang 6 reservoir, and the relationship is as follows:

Por=0.2012× Ac-36.042 r=0.89

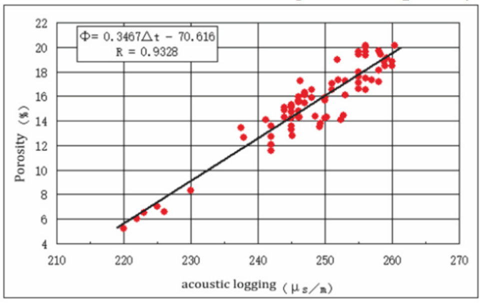


Figure.3 Relationship between Chang 4+5 acoustic logging and porosity

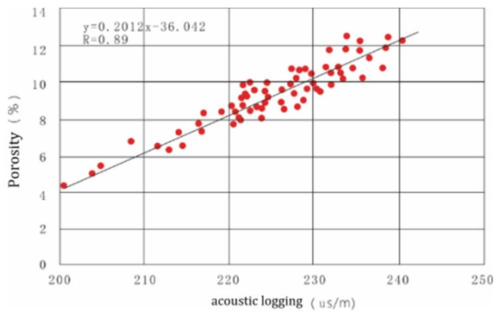


Figure.4 Relationship between Chang 6 acoustic logging and porosity

### 3.2 research on permeability logging interpretation model

There are many factors affecting permeability.The reservoir micro pore structure's complexity dictates a considerable gradient of permeability within the reservoir. Unfortunately, logging information is not able to precisely reflect and explain this change rate. To ascertain the permeability of the reservoir, the core analysis data and logging information of the block are usually used to create a regional empirical formula to gauge the permeability.

The analysis of core data revealed a strong connection between porosity and permeability of Chang 4+5 and Chang 6 reservoirs in the research region. Consequently, porosity was employed to create the interpretation model for gauging permeability, and the correlation is as follows:

Permeability calculation model of Chang 4+5 reservoir: perm=0.0128 × E (0.3711 × POR) r=0.7273

Permeability calculation model of Chang 6 reservoir: perm=0.0089 × E (0.3971 × POR) r=0.6652

Where:

Perm is the analytical permeability of the target interval;

Por is the analytical porosity of the target interval.

The permeability and porosity formula, which is applied to coring wells apart from key wells, has been found to be in good agreement with the core analysis results, thus making it a suitable tool for assessing reservoir permeability.

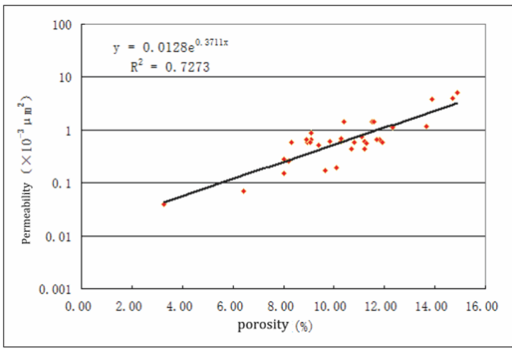


Figure.5 Porosity- permeability relationship of Chang 4+5

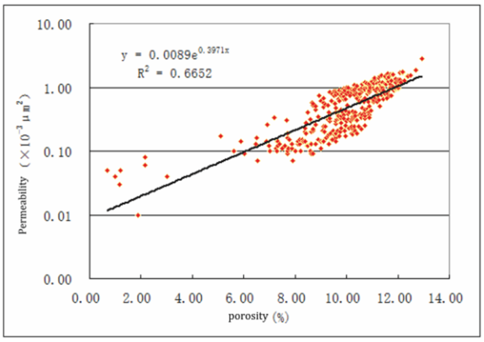


Figure.6 Porosity-permeability relationship of Chang 6

### 3.3 reserve estimation

Based on the values of the oil formation and small layer reserve parameters, the oil geological reserves in the region are escertained by the volume method,. The formula employed is:

$$N=100A_o h \varphi S_o \rho_o /B_{oi}$$

Where, N - geological oil reserves, $10^4$t;

Ao - oil bearing area, $km^2$;

H - effective thickness, m;

φ— Effective porosity,%;

So - original oil saturation,%;

ρo - density of crude oil, $t/m^3$;

Boi - volume coefficient of crude oil.

The oil-bearing area delineated by the Chang 4+$5_1$ sublayer is 5.75 $km^2$, and the calculated reserves are 106.7108×104 T, the oil-bearing area of Chang 4+$5_2$ sublayer is 6.03 $km^2$, and the calculated reserves are 103.5705×104t, with a total oil-bearing area of 4.54 $km^2$ delineated in the $6_1^1$ sublayer, and the calculated reserves of 56.1815 ×104 t, with a total reserve of 266.4628×104 t.

Table.2 calculation of geological reserves

| Horizon | Oil bearing area ($km^2$) | Average effective thickness (m) | Average effective porosity (%) | Oil saturation (%) | Ground crude oil density ($t/m^3$) | Volume factor | Geological oil reserves (104t) |
|---|---|---|---|---|---|---|---|
| Chang4+$5_1$ | 5.75 | 3.99 | 12.71 | 40 | 0.878 | 1.042 | 106.7108 |
| Chang4+$5_2$ | 6.03 | 4.47 | 10.50 | 40 | 0.878 | 1.042 | 103.5705 |
| Chang$6_1^1$ | 4.54 | 3.68 | 10.45 | 35 | 0.869 | 1.058 | 56.1815 |
| total | | | | | | | 266.4628 |

## 4. prediction of favorable areas

The geological basis for exploration and development is predicted to be provided by the favorable exploration area, due to the favorable sedimentary facies belt, sand body distribution, reservoir classification and evaluation, and the existing drilling situation. In the screening, the physical properties and the favorable sedimentary facies belt development areas are mainly taken into account.

### 4.1 prediction of Chang 4+$5_1$ favorable area

There are five favorable oil-bearing areas in Chang 4+$5_1$ of the study area.The sand thickness surpasses 20m, and its porosity surpasses 10% as well. The sedimentary facies are distributed on the main branching of the water diversion channel (Fig.7). Among them, well Kam 13-6 and well Kam 111-2 have a maximum sand body thickness of 34m, and the surrounding well Kam 13-3 and well Kam 13-7 have produced oil; Well Kam 14-1 around well Kam 14 has produced oil.

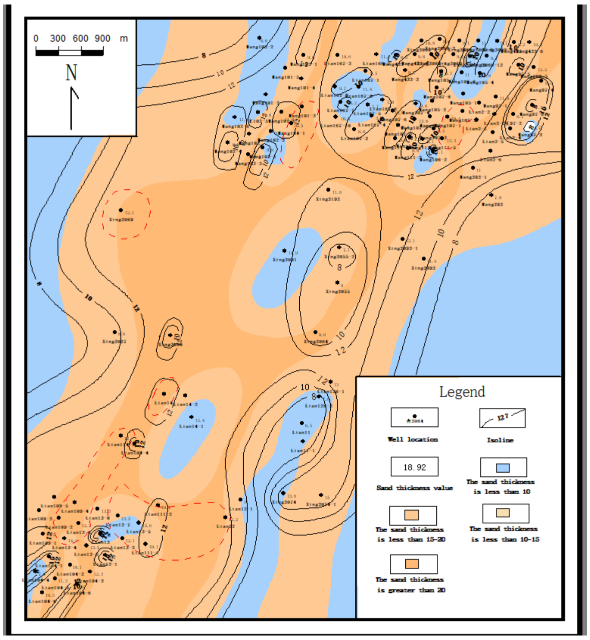


Figure.7 prediction of favorable areas of Chang 4+$5_1$

### 4.2 prediction of Chang 4+5$_2$ favorable area

The favorable oil-bearing area of Chang 4+5$_2$ in the study area is shown in Figure.8. The delineated favorable area is located on the water distributary channel, with sand body thickness greater than 20m and porosity greater than 10%, a total of 7 favorable areas. Among them, well Kam 12-1 around well Kam 12 has produced oil; The maximum thickness of sand body in the region of well sickle 13-6 can reach 34m, and the surrounding well sickle 13-3 and well sickle 13-7 have produced oil; Well Kam 14-1 around well Kam 108-3 has produced oil; Well Wang 102-1 around well Wang 104 has produced oil.

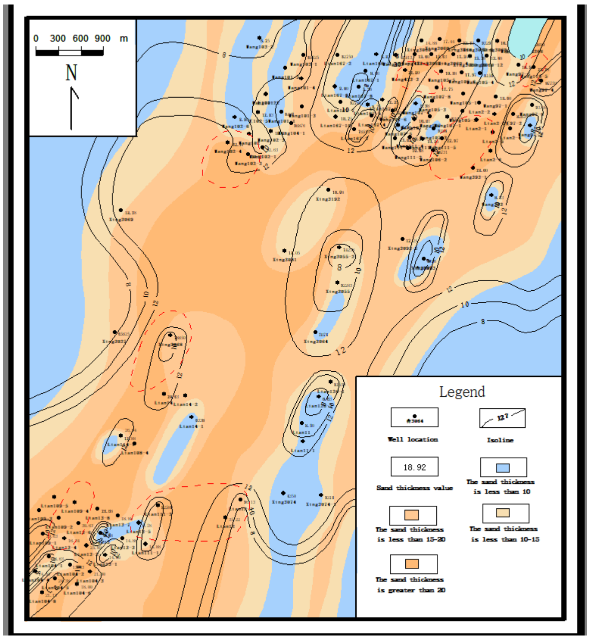


Figure.8 prediction of favorable areas of Chang 4+5$_2$

### 4.3 prediction of favorable area of Chang $6_1^1$

Chang $6_1^1$ is a region of high oil-bearing potential in the study region, which mainly locates in the northeast and middle (Fig.9) on the underwater distributary channel. The sand body thickness is more than 10m, while the porosity is more than 10%. Oil production has been accomplished in wells Kam 167-3 and Kam 167-10 around Kam 167-7.

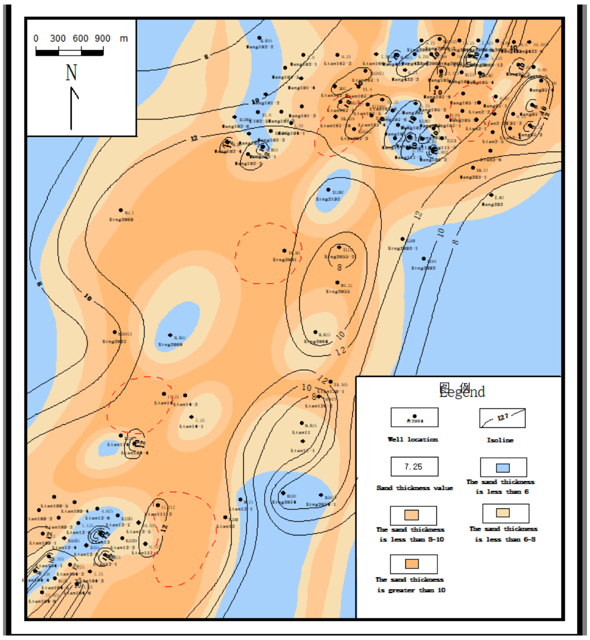


Figure.9 prediction of favorable area of Chang $6_1^1$

## 5. conclusions and suggestions

1. An assessment of the reservoirs in the research region revealed that the Chang 4+5$_1$ sand body was predominantly a Class II reservoir, comprising 47.3% of the entire reservoir population, with Classes III and I reservoirs coming in at 37.5% and 15.2% respectively. The Chang 4+5$_2$ sand body is mainly class II reservoir, accounting for 47.8% of the total number of all types of reservoirs, followed by class III and class I reservoirs, accounting for 35.0% and 17.2% respectively. The Chang 611 sand body is mainly class II reservoir, accounting for 46.2% of the total number of all classes of reservoirs, followed by class III and class I reservoirs, 9% and 13.9% respectively.

2. In this region, the Chang 4+5 and Chang 6 reservoirs are of a lithologic nature, and the layout of oil and gas is largely determined by the lithology and physical features of the reservoir. Generally, the enrichment region of these high-grade reservoirs is the area of oil and gas enrichment. These reservoirs are primarily formed in the delta plain water distributary channel deposits and channel side edges, which are spread out in a band along the plane and strike NE-SW. Both sides of the sand body and the updip direction are interbedded with mudstone and siltstone deposited in the distributary depression, forming the lithologic barrier of Chang 4+5 and Chang 6 reservoirs.

3. due to the poor physical properties of Chang 6 reservoir, the oil-water boundary is not obvious, namely the oil-water is mixed, there exists no distinct oil-water interface, and there is a lack of edge and bottom water. In other words, the reservoir is a typical elastic solution gas drive lithologic reservoir.

4. through the study of reservoir control factors, it is considered that sedimentary facies acts as the foundation for controlling the oil and gas distribution in the study area. Depending on the sedimentary microfacies, logging

interpretation model, combined with the structure and productivity characteristics, through systematic analysis and comparison,15 evaluation targets are finally selected, including 4 class II targets,11 class III targets, and no class I favorable area.

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