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Integrated Geophysical Interpretation in Xi'ling Depression (Bayanhaote Basin), Inner Mongolia, North China

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Abstract: The objective of this study is to use enhanced images of the seismic depths and/or geologic information integrated with gravity models, using 2.5-D interactive forward modeling, to give an improved model of subsurface structure in the vicinity of lines X5 and X6, in Xi'ling depression (Bayanhaote Basin), Inner Mongolia, North China. Gravity and seismic data are good complementary methods in that: seismic data can provide constraints on sub-horizontal interfaces, whereas gravity data image steep boundaries well (Location of faults or fault zones). The integrated interpretation is expected to eliminate the ambiguity inherent in the potential field method, can reveal the best situation of sub-surface geology, delineate the geometry of the depression and also the estimated depths to the basement surface. Meeting with the need of oil exploration, this equivalent to determining the types and the maximum thickness of the sedimentary section.

Key words: Integrated interpretation, Xi'ling depression, basement surface

INTRODUCTION

Bayanhaote basin lies in the area between latitude 37°20`-39°30`N and longitude 103°-106°E, (X (vertical coordinates): 4140000~4380000, Y (horizontal coordinates): 18300000~18580000), Inner Mongolia, North China (Fig. 1). The direction of the basin is NE direction with a triangle shape. The total area of the basin is 20000 square km.

The Bayanhaote basin lies on the west of Inner Mongolia Autonomous region between Helan and Bayanwula Shan Mountains, where is the interjunction of Ordos Massif, Alashan Massif and Qilian Shan folded belt.[1] divided Bayanhaote basin into six secondary units, three depressions, two uplifts and one slope.

- West depression belt.
- East depression belt, (Xi'ling depression)
- South depression belt.
- Central uplift belt.
- East slope belt.
- South uplift belt.

East depression belt (Xi'ling depression): Xi'ling depression lies on the east part of the central lift. The east margin of this depression is near the East slope belt. The total area is about 4000 km^2. The west and east parts of the depression are sloping towards the Central belt and East slope belt. The strata that overlain the crystalline metamorphic basement are composed of Ordovician, Carboniferous, middle to late Jurassic and late Cretaceous age. The Bacan 2 well confirmed the existence of late Paleozoic sediments (Carboniferous sediments) and there is Paleozoic sediments that belong to Ordovician period. This depression has great depths to the basement. The

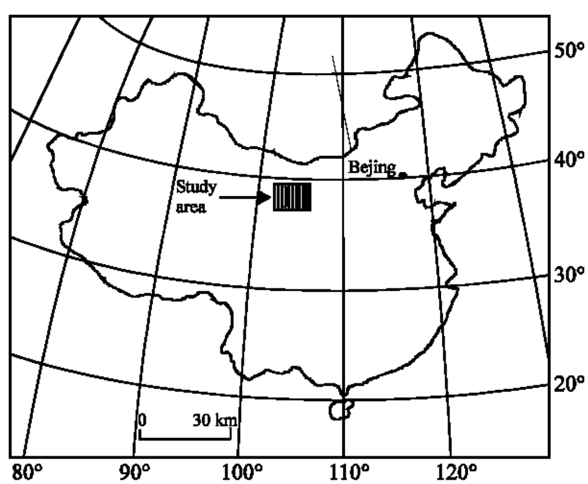

Fig. 1: Location map of the study area

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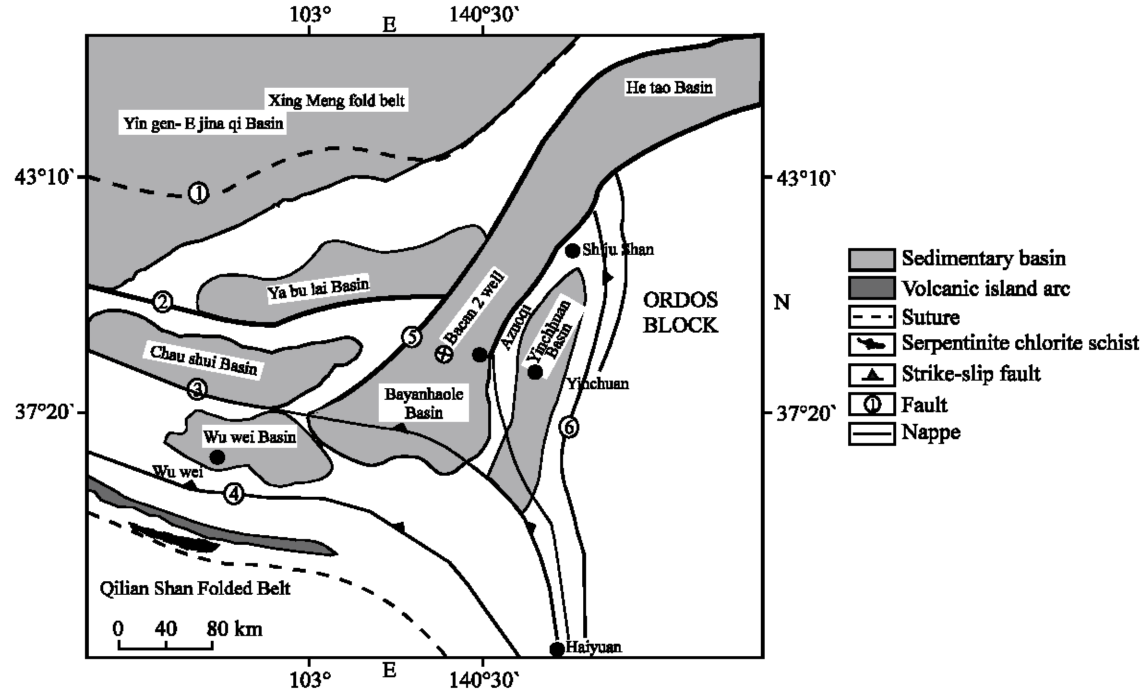

Fig. 2: Location map of the regional tectonics of Bayanhaote Basin and surroundings. (Modified after Xiong Bao Xian *et al.*[4])
1) North suture of Alashan block 2) Bei da Shan boundary fault 3) Long Shoushan-qing tong xia fault 4) Qilian Shan north boundary fault 5) Bayanwula Shan-Lang Shan fault belt 6) West boundary of Ordos fault belt

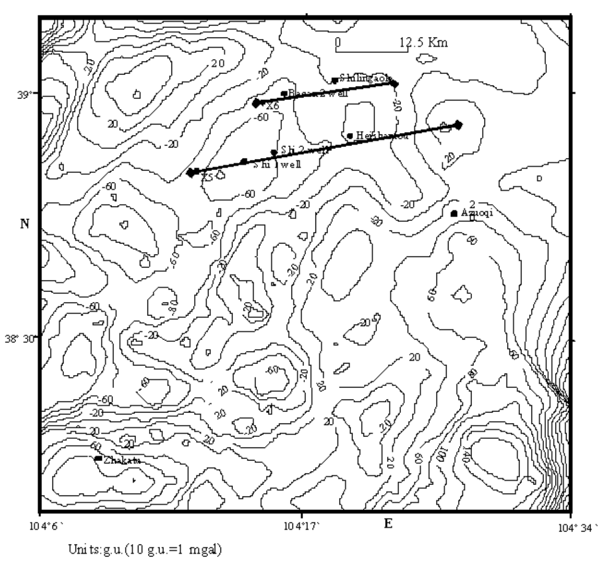

Fig. 3: Residual anomaly map of Xi'ling depression (Bayanhaote basin)

cover strata are integrity and the scale of the extension is large. According to Liu[1], this depression can be divided into 14 subunits.

General tectonic setting of bayanhaote basin: The Bayanhaote basin is a complex basin at the region of Hua bei block (North China Block). It is a part of three big geological units (Alashan massif, Ordos's block and Qilian Shan folded belt), (Fig. 2). Faulting is the main factor in the formation and evolution of the basin[2]. According to subsidence and uplifting stages in the basin, four types of basins were formed during Silurian-Permian, Carboniferous-Permian, Middle Jurassic-Early Cretaceous and Cenozoic, respectively. In Early Cretaceous, the whole basin subsided and become a unitary basin[3]. It is a compound and superimposed basin formed from different periods and many times of tectonic movement reformation. According to the development property of structure as well as the relation between regional tectonic evolutions, Xiong Bao-Xian *et al.*[4] considered that the Bayanhaote basin and its peripheral regions experienced the evolutionary stages of the Early-Middle Qin-Qi He Trigeminal Rift, the Late Proterozoic-Cambrian-Ordovician Aulacogen, the Silurian-Devonian Foreland Basin, the Carboniferous-Permian Compound Basin and the Mesozoic-Cenozoic Fault Basin.

The basin is generally composed of three layers: shallow layer, middle layer and deep layer. The shallow layer is composed of weak deformed Mesozoic formation and non-deformed Cenozoic formation, including normal faults. The middle layer is composed mainly of deformed Paleozoic formation, including huge folds and pressure faults. The deep layer is composed of vividly deformed Archaeozoic-Proterozoic metamorphic rocks, including flow folds and ductile shear belt.

Residual anomaly map of Xi'ling depression: The residual anomaly map of Xi'ling depression was prepared by using a software (PGMS) version 2.0 for Gravimagnetic data processing system such as using 3-D potential field transform system in frequency domain.

The residual anomaly map of Xi'ling depression, (Fig. 3), reflects the effect of the anomalous sedimentary fill in the study area. The map reveals areas of gravity high and areas of gravity low and sharp gradient belts. The low and high gravity anomalies reflect lifts and depressions while the steep gradient belts reflect structural geological boundaries. Initial structural analysis of the gravity data indicated that there are three sets of faulting exists in the Xi'ling depression. Their trends are northeast-southwest, east-west and north-south directions. The intersection of these faults may serve as hydrocarbon barriers or structural traps.

Integrated interactive forward modeling: The forward modeling is discussed by Blakely[5], Grant and West[8]. The interpretation of gravity tightly integrated with seismic information or previous potential field studies, or other kind of geophysical/geological information may be available to guide the modeling and design it as realistic as possible. In this context, a 'realistic' model means, those inconsistencies of existing information should be restricted to a minimum. The structures (geological bodies) to be modeled are bounded by triangulated surfaces (layer boundaries), which limit domains with constant density and/or susceptibility. A basic requirement for modeling is the existence of ideas and hypothesis on the investigated area, i.e. the availability of quantitative or qualitative constraints. Rapid computation of interpretive operations provides virtual, real-time analysis of interpretation hypotheses. Towards this end, geophysical forward modeling aims in the combination and compilation of (all) existing information. In other words, the interpretation in any case will be inherently non-unique, but incorporation of independent information may reduce the infinite set of mathematical solutions to a manageable array of models, still infinite in number but at least more geologically reasonable.

An interactive 2-1/2D forward modeling program that uses standard Talwani-type polygonal modeling procedures[9] to update the computed gravity field in real-time as the model is changed.

Input models can be digitized directly from seismic or geologic interpretations. Then geologic information must be added to the model and forward modeling is performed to create reasonable matches between the calculated and observed gravity field, honoring the known geologic constraints.

Two gravity profiles (X5 [length: 50 km] and X6 [length: 25 km] with 250 m point space) are integrated with other geological and/or geophysical information to delineate the sub-surface structural situation and the estimated depths to the basement surface.

RESULTS AND DISCUSSION

X5 Line: From the interactive forward inversion results of the gravity and seismic depths (Fig. 4) and the seismic section (Fig. 5), it can be concluded that the mass distribution of geologic section can be delineated and has a certain function of imaging. The interactive inversion of this profile have the following characteristics: Around 13000 gravity point is the reflection of the thrust fault west to the Heishantou which is called Xilinggaole fault. Also the point gravity number 48000 reflects the Azuoqi fault and point's number of 20000, 24000, 30000 and 35000 are all reflection of faults. The broken upheaval of the Cambrian-Ordovician period between the point number 13000 and 30000 can be clearly seen on Fig. 4. The gravity points between 13000 and 20000 are corresponding to the Cambrian strata and what's wrapped by the fault between the points 20000 is the reflection of the Ordovician strata and another Cambrian broken block can be seen between the point number 24000 and 30000. Also the depth variation of the Ordovician strata can be seen at 30000 gravity point. The gravity point of 48000 indicates drop which is the same with the drilling well at the eastern of the gravity point 10000. The section below the point 10000 shows that the Cambrian-Ordovician stratum has a large burial depth of Carboniferous strata.

X6 Line: This line has no seismic data as a reference; therefore, we had carried out the interactive inversion by drawing on the inversion results obtained from line X5. The results can be seen in Fig. 6. The Bacan-2 drilling well, located approximately at 4900 gravity points, indicates that the top surface of the Carboniferous strata has a depth of 2865 m, while its bottom is at depth of 3950 m. Eastward, there is a positive fault at the gravity number 7000, with high-density Cambrian strata thrusting up at its eastern side. According to the interpretation module of line X5, there is no Carboniferous strata distributed in the

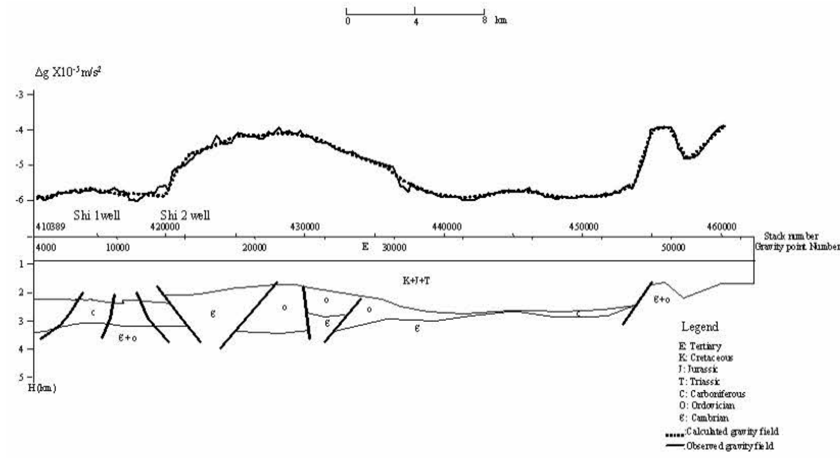

Fig. 4: Interactive forward inversion result of X5 line in Xi'ling depression (Bayanhaote basin)

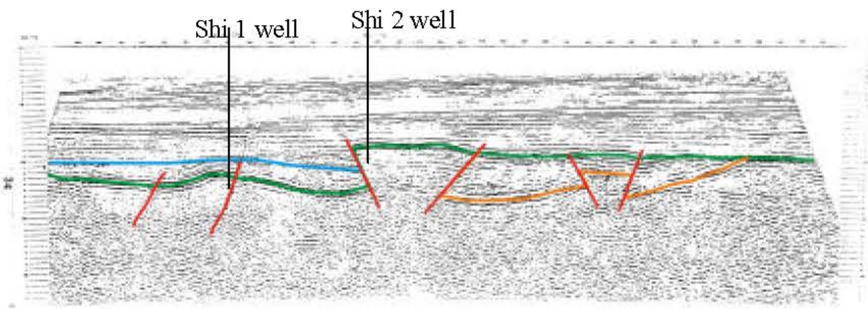

Fig. 5: Seismic section of X5 line in Xiling depression (Bayanhaote basin)

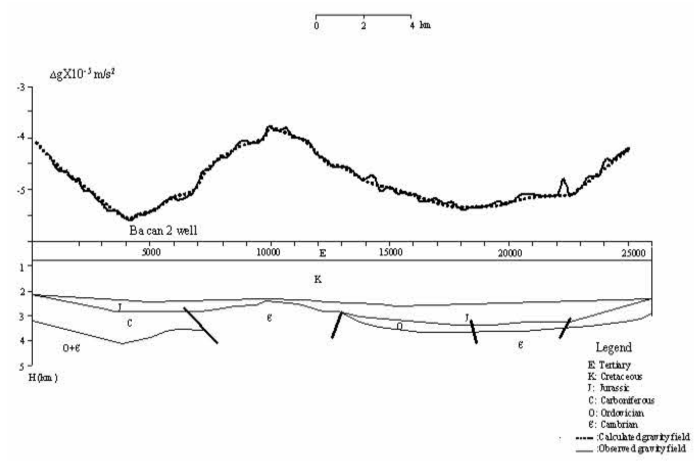

Fig. 6: Interactive forward inversion result of X6 line in Xi'ling depression (Bayanhaote basin)

eastern parts of the upheaval in the Cambrian strata and relatively thin Ordovician strata may be lies under the Jurassic strata.

Bayanhaote basin is a multiple-overlapping basin, which had developed various structural patterns due to its special structural location and complex structural evolution history. Accordingly, different structural patterns accompanied with different trap types were developed[10]. Therefore, Bayanhaote basin is a favorable hydrocarbon accumulation belt and trap types include extensional fault block traps in the northern, Compressional anticlinal traps in the southern and stratigraphic unconformity traps in the eastern[11]. The structural analysis of the gravity data indicated that there are three sets of faulting exists in the Xi'ling depression. Their trends are northeast-southwest, east-west and north-south directions. The intersection of these faults may serve as hydrocarbon barriers or structural traps.

Gravity and seismic data are good complementary methods in that: seismic data can provide constraints on sub-horizontal interfaces, whereas gravity data image steep boundaries well (Location of faults or fault zones). Therefore, the integrated methods carried in Xi'ling depression revealed the sub-surface geological and structural situation of the depression and also the estimated depths to the basement surface. From drilling results of Bacan well 2 confirmed that there is an old Carboniferous strata preserved at depth more than 1000m of which Yanhugou formation (main-oil stratum) thickness is 459.6 m[12]. This borehole shows 26 oil indications in middle Carboniferous series. The thickness of oil-bearing sandstone is 89.6m.This oil-bearing strata confirmed that the Carboniferous stratum, which is mainly mud rock, is the target stratum of oil production in Xiling depression.

So the distribution and existence of the Carboniferous strata interrupted by faulting system confirmed that this stratum is provided with good trap conditions, thus possessing a favorable oil and gas potentia[10,12,13] considered that based on the analysis of the petroleum conditions, the area of Heishantou-Tonggulou anticline structural belt (Xi'ling depression, East depression belt) is the most favorable potential oil and gas exploring area in the whole basin.

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