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Acquisition and Preparation of 3D Seismic Data for Pre-Stack Inversion at Siba Oilfield, Southeastern Iraq

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Abstract

The current study includes preparing a geometric proposal of the main parameters that must be worked within a seismic reflection survey to prepare a three-dimensional subsurface image. This image represents the Siba oil field located in Basra, southern Iraq. The results were based on two options for selecting these approved elements to create a three-dimensional image of the Mishrif, Zubair and Yamama formations as well as the Jurassic and Permian Khuff and the pre-Khuff reservoir area. The first option is represented in the geometry in option -1 is 12 lines, 6 shots, and 216 chs. The receiver density is 66.67 receivers / km^2, so the shot density is the same. Total shots are 21000, which is the same number of receiving points. The survey area (in km^2) and full fold area (in km^2) are 317and 328, respectively. However, the second option in the geometry are16 lines, 16 shots, and 208 chs. Receiver density and shot density are 50, while the total shots are 16200 and the total receiving points are 16000; with survey area and full folded area are 198 and 198 km^2. The aim of the current study is to characterize the structure and reservoir quality of Yamama and Zubair intervals and to image potential exploration targets such as the Mishrif, Jurassic, Permian Kuff and Pre Khuff formations. The present study succeeded in preparing the geometric proposal and getting at a subsurface image of the reservoir in three dimensions.

Keywords: geometric proposal; Siba oil field; 3D seismic image; Pre stack Inversion.

استحصال البيانات الزلزالية الثلاثية الابعاد لتلائم المعكوس المسبق التكدس في حقل السيبة النفطي جنوب شرقي العراق

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الخلاصة

تتضمن الدراسة الحالية إعداد مقترح هندسي للمعاملات الرئيسية التي يجب إعدادها والعمل معها لإعداد صورة ثلاثية الأبعاد تحت السطح. هذه الصورة يمثلها حقل السيبة النفطي الواقع في البصرة جنوبي العراق. استندت النتائج إلى اختيارين لاختيار هذه العناصر المعتمدة لإنشاء صورة ثلاثية الأبعاد لتكاوين المشرف

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والزبير واليمامة ، وكذلك الجوراسي وتكوين الخف البرمي، ومكامن ما قبل الخف. يتم تمثيل الخيار الأول في الشكل الهندسي في الخيار -1 وهو 12 مسارًا و 6 نقاط لمصدر الطاقة و 216 قناة ، كثافة المستقبل هي 66.67 مستقبل / كم 2 ، لذا فإن كثافة التفجير هي نفسها. إجمالي نقاط التفجير وصل الى 21000 وهو نفس عدد نقاط الاستلام. تبلغ مساحة المسح (بالكيلومتر 2) ومنطقة التغطية الكامل (بالكيلومتر 2) 317 و 328 على التوالي. ومع ذلك ، فإن الخيار الثاني في التصميم هو 16 مسارًا و 16 نقطة تفجير و 208 قناة, كثافة المستقبل وكثافة نقاط التفجير 50 ، في حين أن إجمالي اللقطات 16200 وإجمالي نقاط الاستقبال 16000 ؛ مع مساحة المسح ، ومساحة التغطية الكلية هي 198 و 198 كيلومتر مربع. الهدف من الدراسة الحالية هو توصيف تركيبية وجودة المكمني لفترات اليمامة والزبير وتصوير أهداف الاستكشاف المحتملة مثل تكوينات المشرف وتكاوين الجوراسي والخف والبرمي. كما نجحت الدراسة الحالية في إعداد الاقتراح الهندسي والتوصل إلى صورة تحت سطحية للخزان بثلاثة أبعاد.

1. Introduction

Seismic properties are derived from large amounts of seismic data to allow the user to interpret the work of a non-traditional investigation of reservoir characterization [1], [2]. Seismic attributes help to improve the mechanics of geological interpretation and provide subsurface images via seismic data [2], [3], [4]. This can be applied to other features, such as pre-stack amplitude versus offset (AVO), which is applied to the seismic data after the stack [5]. It can be measured by the seismic characteristics of time and amplitude, frequency attenuation, or combinations of those parameters [6]. Several studies have concluded that the use of seismic elements is a good tool for calculating the seismic properties of a region [7], [8] [9].

Most geophysical methods that can penetrate to a sufficient depth lack the precision to complete drilling effectively. Seismic surveys are one of few methods with sufficient depth precision to restrict geological models of ore deposits to the drill gauge. Seismic reversal methods can partially reduce the cost of drilling by concentrating drilling in key strategically important areas [10]. Although a series of studies are currently underway, there are not many published reports on using 3D reflection seismic methods for deep mapping in the crystal environment, particularly in Europe. 3D seismic reflection methods have been used in South Africa with encouraging results, allowing imaging of fault systems that, in turn, control the geometry of the ore horizon. [11], [12], [13].

The comprehensive survey of Iraq by foreign companies (1959–1960) produced a map of Bouguer anomalies for the study area and its surrounding areas. This map shows a steady slope towards the north and the location of the Siba oilfield that is characterized by a breakthrough in the lines of gravitational levels with some dents in those lines, indicating a low gradient slope [14]. The magnetic survey map revealed the presence of magnetic anomalies with a capacity of less than 10 gamma stretching toward the EW over almost all of Siba's installations.

Previous seismic surveys and studies include a reconnaissance survey of the independent prospect/SSL company, with the implementation of eight single-coverage seismic lines that covered the southern part of the field with single coverage. The survey focused on the northern part of the area, and among the results of the survey was the presence of a synthetic phenomenon whose axis extends in the direction of northeast-southwest. It consists of two structural culminations separated by subtle saddle as indicated by the study of reinterpretations of seismic information in the siba field, 1993. The second study is a seismic survey of the Faw area conducted in 1969 for the company's benefit by a French company (C.G.G) [15].

One of the recent studies in Iraq is the study of seismic characteristics that give evidence for the presence of hydrocarbons associated with phenomena such as the heap, which is a flat spot within the Zubair Formation [16], [17].

The current study aims to characterize the structure and reservoir quality of the Yamama and Zubair intervals and to image potential exploration targets such as the Mishrif, Jurassic, Permian Kuff, and Pre-Kuff formations [18], [19], [20], and [21]. 3D data acquisition is to be designed so that the resultant data is suitable for pre-stack inversion studies using offset/azimuth dependent seismic attributes (AVO/AVA) for qualitative and quantitative characterization of potential reservoirs.

2. Methodology and Site Description

The study area is located in southeastern Iraq, within the administrative boundaries of the Basra Governorate, and it is about 30 km southeast of Basra City (Figures 1 and 2). The area is bordered on the north and northeast by the Shatt Al-Arab, representing the political borders between Iraq and Iran. The area coordinates were determined according to the U.T.M system with six stations, as shown in Table 1. The area of the field is flat and low topography, with an average height of about 2 meters above sea level, and modern sediments cover the area that is generally formed from floodplain sediments and estuarine slurries, which consist of clay materials and salt marshes.

Table 1- The coordinates of the area were determined according to the U.T.M system

Station No.	N	E
1.	3352500	781000
2.	3373500	781000
3.	3373500	798500
4.	3366000	806000
5.	3358500	809000
6.	3352500	809000

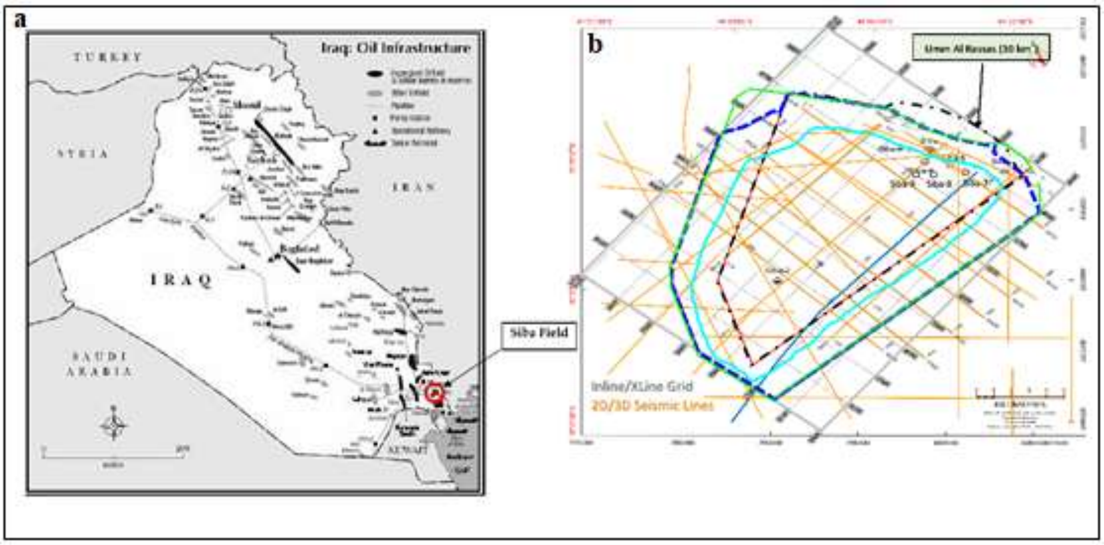

Figure-1 a) Map of Iraq showing the location of the study area, b) Base map of contract area and 2D seismic lines (modified from [20])

The field of the current study is an anticline, NE-SW trending structure. Based on 2D seismic acquired in 1968, the exploratory well Siba-1 was drilled [22]. Additional 2D seismic lines were subsequently acquired in different vintages, and two appraisal wells, Siba-2 and Siba-3, were drilled in 1974 and 1992, respectively. The field has been predominantly gas-bearing in the Yamama reservoir and oil-bearing in the Zubair reservoir [23]. The gas-bearing Yamama

Formation is the primary target for gas development in the Siba field. A generalized lithostratigraphic column for Siba is given in Figure 3.

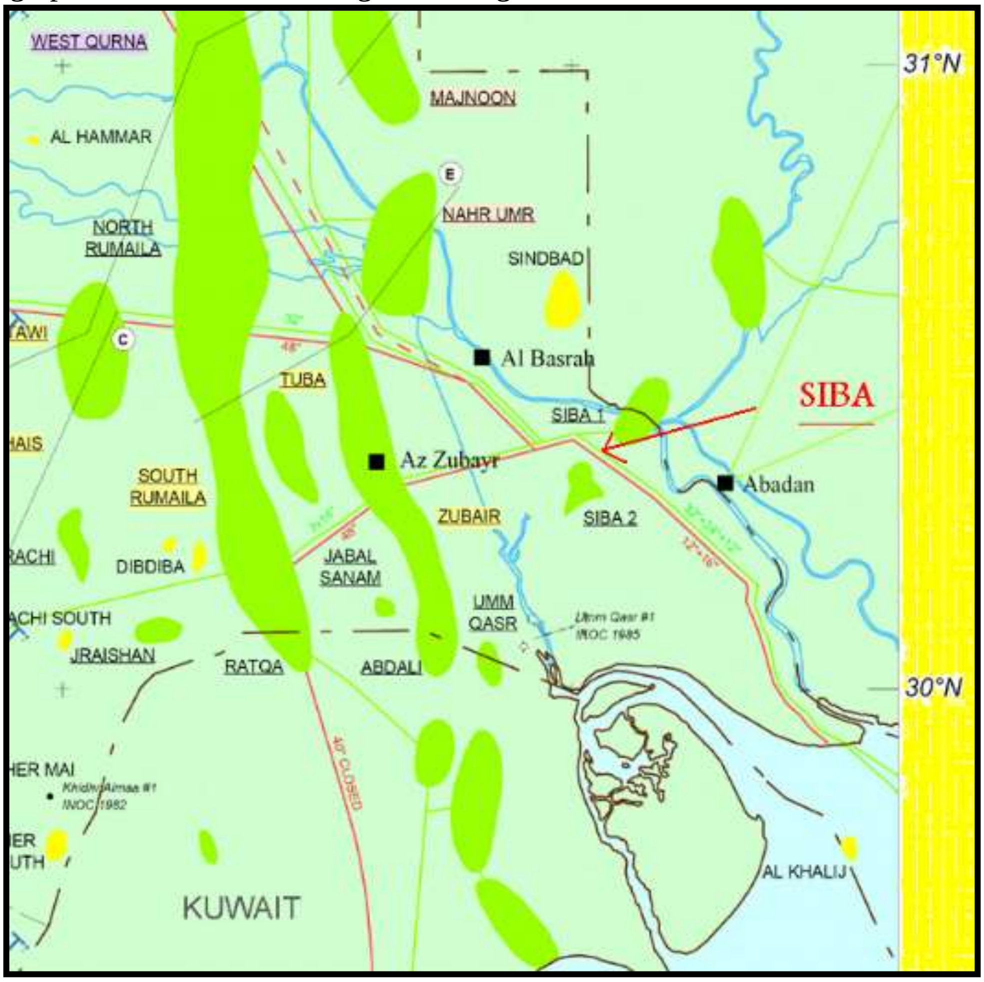

Figure 2-The borders of the Siba field area in southern Iraq [15]

The total length of the seismic lines included in the study of the current reinterpretations was 165 km, which included the lines executed by the second Iraqi seismic group (amphibious) and marked (Sa) within the seismic survey of the Siba field (1993-1994). The quality of the seismic sections is generally good to very good. Five reflectors were captured during the Cretaceous period Mishrif, Nahr Omar, Shuaiba, Zubair, and Yamama. Continuity at the level of good reflectors of Mishrif, Nahr Omar, and Shuaiba or the level of Zubair and Yamama reflectors is weak in some parts of the area.

The study area's three wells (Sb-1, Sb-2, and Sb-3, the well Sb-1) relied upon the velocity scanning points and the availability of some of the probes used in the manufactured trace. The other two wells were not used for this purpose due to the lack of sensors. A complete well Sb-2, while the well siba-1 does not have quick scan points, was captured through the manufactured trace.

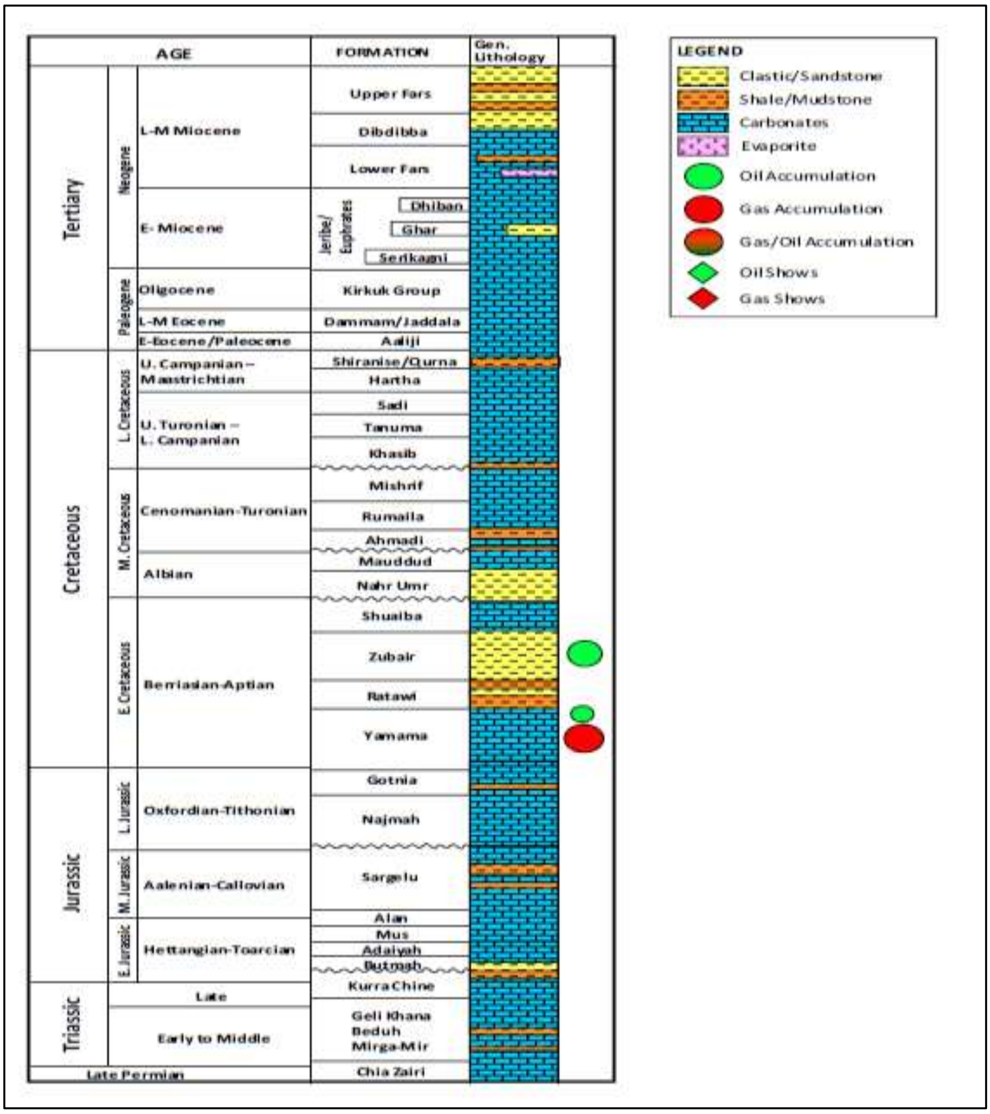

Figure 3-Generalized lithostratigraphic column of Siba oilfield [24].

3. Results and discussion

The lower Aptian-Barremian Zubair Formation is an alternating sandstone-shale sequence with thin limestone streaks and has a gross thickness of 300-350 m [25]. The Ratawi Formation is interbedded limestone and shale [26]. Depth information for the desired targets was obtained from reflection time Information (Two Way Time or TWT) at target horizon levels (Table- 2).

Table 2- Depth/Reflection Time Values at Target Horizon Levels

Reservoir Zone	Depth (m)	TWT (ms)	Focus
Mishrif Formation	2440-2540	1480-1550	Exploration Target
Zubair Formation	3420-3560	1920-1980	Development Target
Yamama Formation	3860-4040	2120-2220	
Jurassic intervals	4460-4660	2420-2500	Exploration Target
Permian Khuff and Pre Khuff	5680-5980	2980-3100	

The lower Cretaceous Yamama Formation is a massive but heterogeneous carbonate reservoir with an average gross thickness of over 200 m [27]. This formation consists of limestone, vugular and sometimes recrystallized, intercalated by shale or marl laminations, separating the formation into different reservoir quality and hydraulic carbonate units (Figure 4).

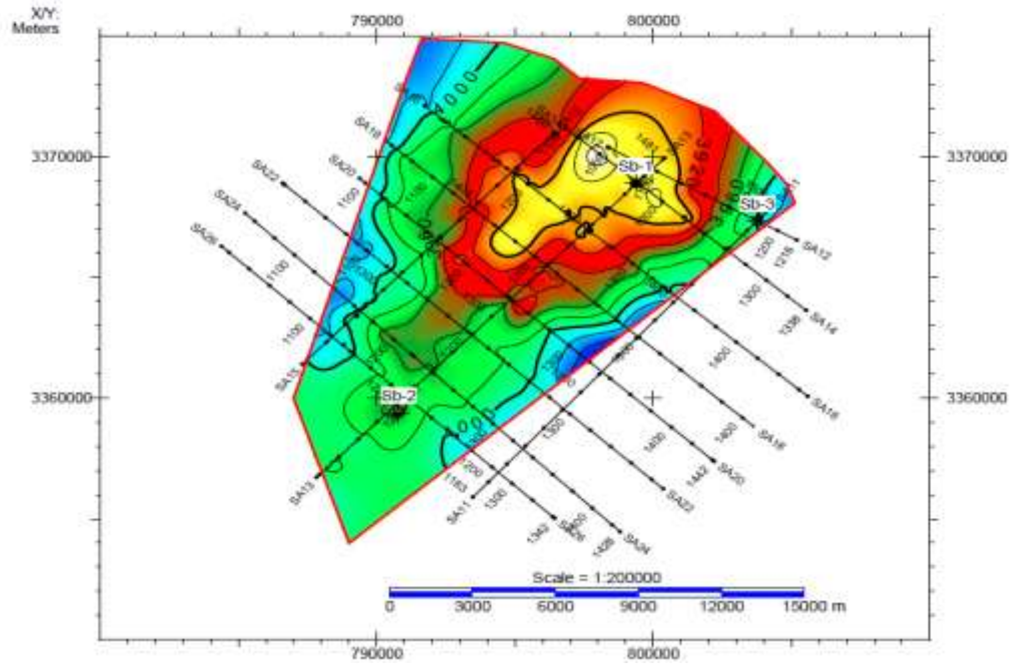

Figure 4-Depth map of the lower Cretaceous Yamama Formation.

3.1 Existed Data Analysis

3.1.1 Acquisition Parameter Analysis

The existing data consists mainly of 2D seismic data from 1993 to 1994. The data acquisition parameters of Siba lines (SA lines) are as below:

One hundred twenty active channels, 100 m shot points interval, Source type: Dynamite, Shot Hole: unidentified, charge size is unknown. Offsets: SA Lines are 1200 m – 50 m – *-50 m – 4800 m, folds are 30, and the data length is 4800 m. SA and record length 5 seconds.

3.1.2 Existed Seismic Section Analysis

The typical section is shown in Figure 5. This area's main reflection layers are evident, showing that the data has a higher S/N.

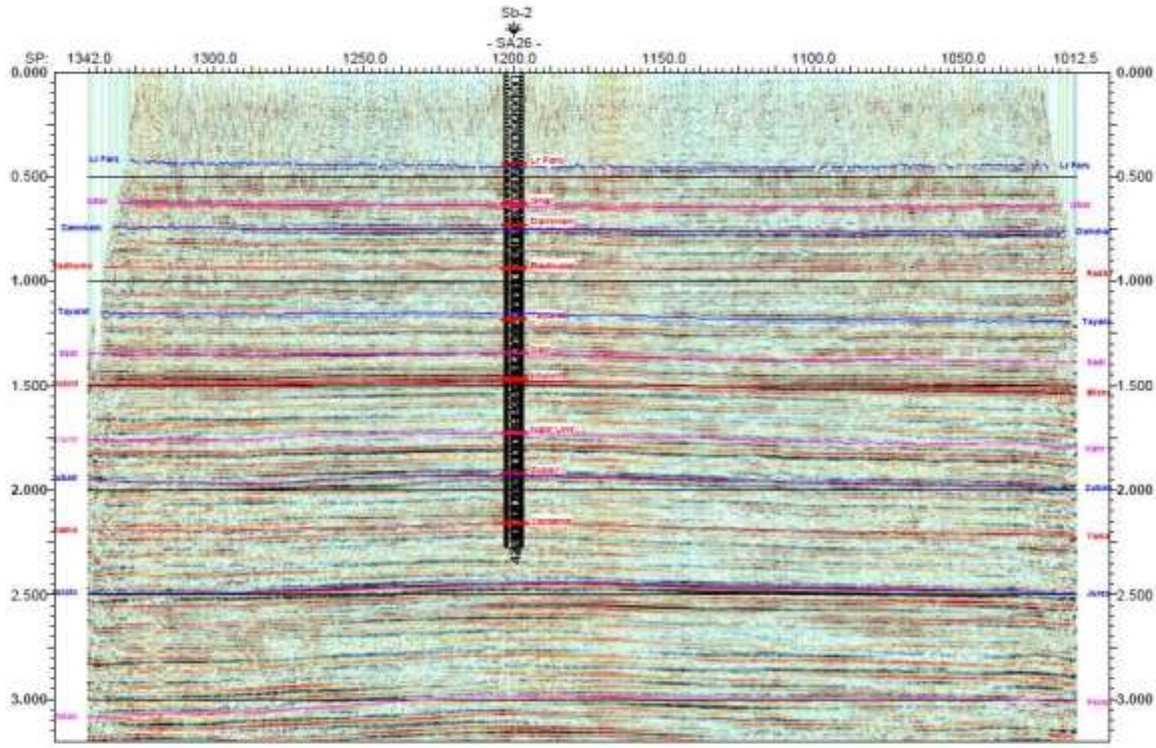

Figure 5-Representative 2D seismic line SA-26.

3.2 Acquisition Parameters Design and Proposal

3.2.1 Geometry Design

Key acquisition parameters, such as bin size, offset and folds etc., shall be considered in geometry design based on the exiting 2-D data and geological objectives. Based on the data of Siba-3 Well, structure maps and velocity maps, the geophysical model parameters listed in Table 3 were selected for the area.

Table 3- Geophysical model parameters of the studied formations.

Formations	TWT (ms)	V_{ave} (m/s)	V_{int} (m/s)	H(m)	Dip (deg)	F_{max} (Hz)	F_{dom} (Hz)
Mishrif	1512	3287.0	4500.0	2485	2	50	36
Zubair	1940	3636	5000	3520	2	45	32
Yamama	2160	3710	4170	4000	2	40	29
Top Jurassic	2470	3740	?	4600	2	35	25
Permian Khuff and Pre Khuff	3080	3890	?	5600-6000	2	30	21

3.2.2 Vertical Resolution

If there is no coherent noise, the vertical resolution of seismic wave is a quarter of its wavelength. i.e.:

$$D_r=V_{int}/4F_{max} \qquad \text{……………. (1)}$$

Where D_r is Vertical resolution (m), V_{int} is the interval velocity of the layer (m/s), and F_{max} is the maximum frequency of the layer (Hz). The vertical resolution was calculated using KLSeis and shown in Figure 6. If the highest frequency of the Mishrif layer reaches 50Hz, the vertical resolution is 22.5m. If the highest frequency of the Zubair layer reaches 45Hz, the vertical resolution is 27.8m. If the highest frequency of the Yamama layer reaches 40Hz, the vertical resolution is 26.1m. If the highest frequency of the Jurassic layer reaches 35Hz, the vertical resolution is 32.8m. If the highest frequency of the Permian layer reaches 30Hz, the vertical resolution is 37.7m.

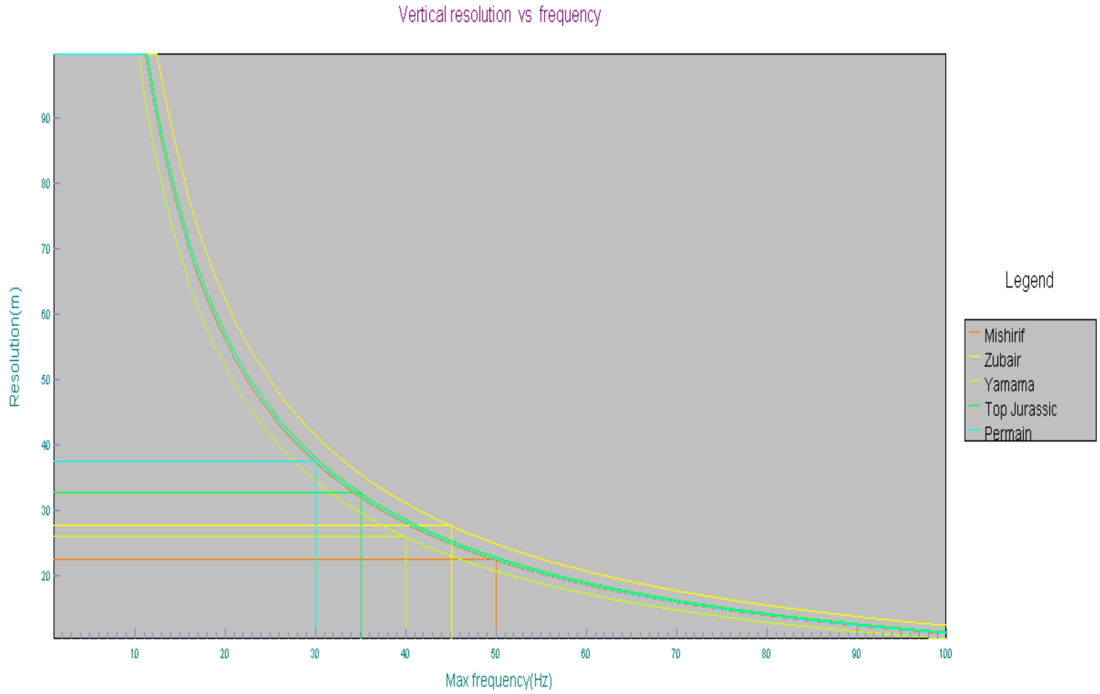

Figure- 6 Vertical Resolution of the study area.

3.2.3 The Selection of Folds

Representative 2D seismic line SA-26 (Figure 5) with 30 fold shows that the existing sections have a higher S/N ratio in this area, so 30-fold coverage for the planned 3D seismic project should be able to get better data. Therefore, due to AVO/AVA analysis is requested, the fold should be much higher than 30 to ensure enough fold coverage within different azimuth ranges. Therefore, about 120 folds are proposed for the depth (5500-6000m) in the study area to be used in 3D seismic reflection.

3.3 The Selection of Maximum Offset

3.3.1 The depth of the target

Xmax should be equal to the target depth approximately. Almost 120 folds at 5500 to 6000 m deep were proposed for this project to be used in 3D seismic reflection. Based on Table 2, the maximum offset for this project shall be 5500-6000m.

3.3.2 Velocity analysis precision

During the data processing, enough spread length is required to get the accurate stack velocity. The relation between the maximum offset and the velocity analysis precision is shown below.

$$X \geq \left(\frac{2T_0}{F_P\left(1/\left(V^2(1-P)^2\right)-1/V^2\right)} \right)^{\frac{1}{2}} \qquad \text{................ (2)}$$

Where P- velocity analysis precision, X-maximum offset length, F_p- effective domain frequency and domain frequency and V- average square root velocity [7].

The analysis result by KLSeis is shown in Figure 7.

If the velocity analysis precision is selected as 6%, then:

Mishrif layer: Xmax> 1863m, Zubair layer: Xmax> 2455m, Yamama layer: Xmax> 2804m, Jurassic layer: Xmax> 3224m, and Permian layer: Xmax> 4067m.

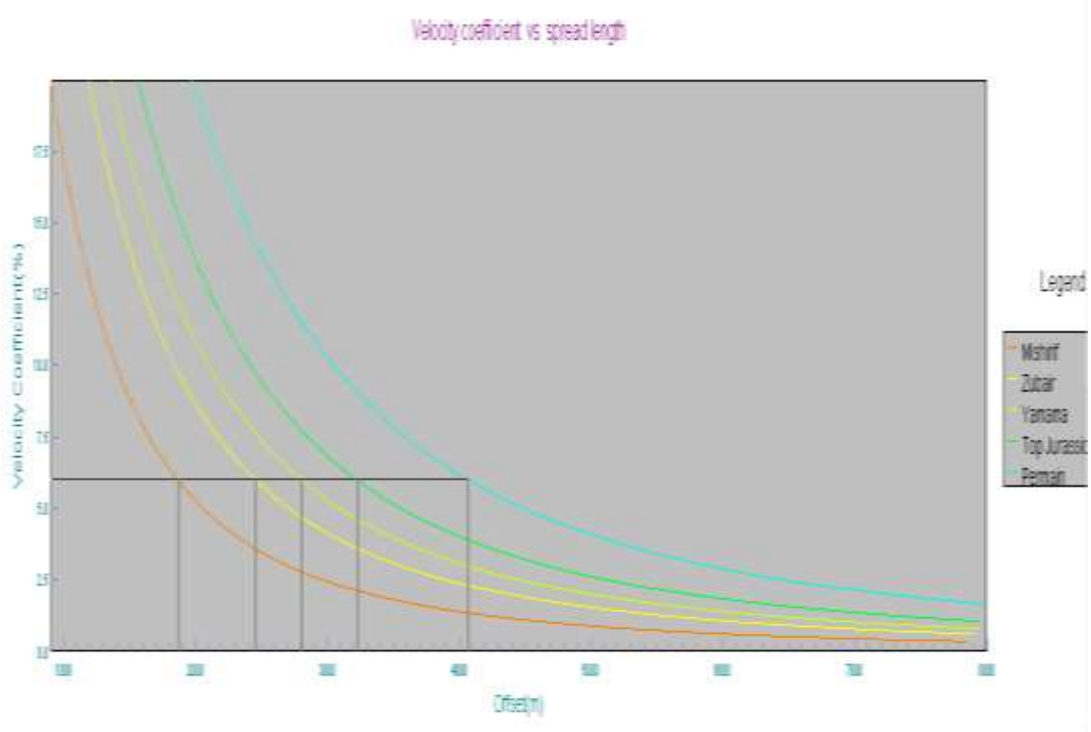

Figure 7-Relation between offset and velocity analysis precision

3.3.3 The requirements of Normal Move out (NMO) stretch

The process of NMO correction removes the move-out effect on travel times, which processing will generate data distortion, especially at the long offset portion. It also decreases the data frequency. The formula of the relation between the NMO distortion and maximum offset is shown below [7].

$$D = \frac{X^2}{2T_0^2V^2} \times 100\% \qquad \text{…………….. (3)}$$

Where D is the percent of the NMO stretch, X-maximum offset length, T_0-two ways travel time at zero offset, and V-root mean square velocity

Suppose the NMO stretch is no more than 12.5%. The analysis result by KLSeis is shown in Figure 8.

Mishrif layer: Xmax < 2557m, Zubair layer: Xmax < 3622m, Yamama layer: Xmax < 4116m, Jurassic layer: Xmax < 4734m and Permian layer: Xmax < 6174m.

4. Reflection Coefficient Stability

Energy decay varying with incidence angle will occur due to the energy loss by transmission and reflection when a seismic wave meets the resistance interface. Therefore, it is necessary to consider the optimum maximum offset in designing the geometry. During P-wave exploration, when the incident angle at the reflection

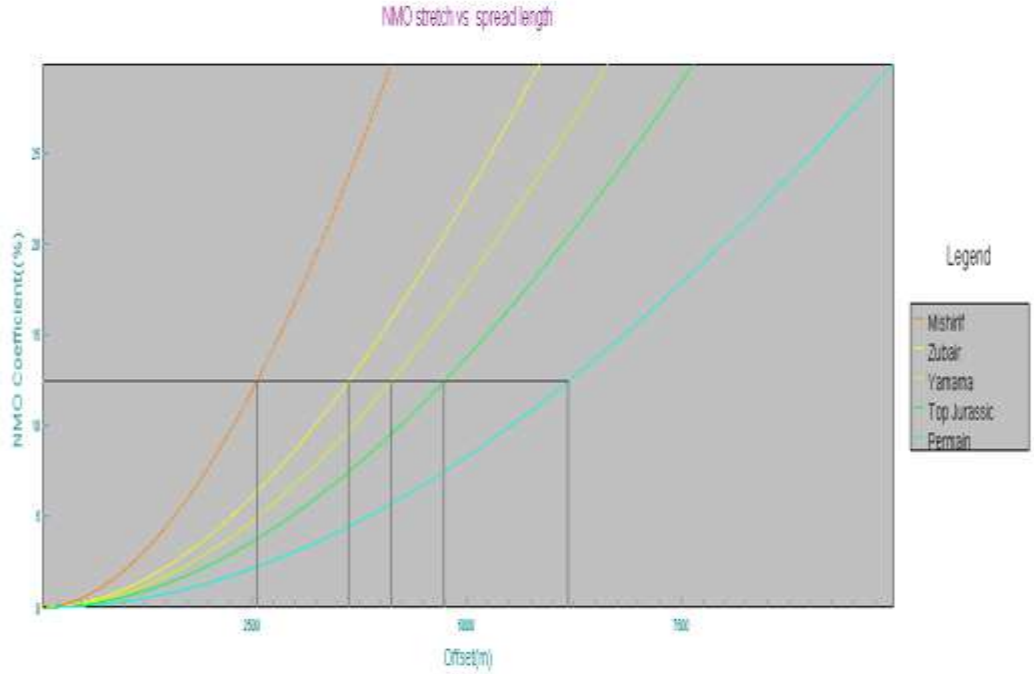

Figure 8-Relation between offset and NMO stretch

The interface is less than the critical angle; reflection energy is stable. Therefore, the spread length can be determined by reflection energy. The formula is as below [7].

$$x \leq \sum_{1}^{N} H_i tg\theta i \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Where, Hi —thickness of the layer I, θ_I —the critical angle of the layer i and x —Maximum offset

The relation between reflection coefficient and maximum offset demonstrated by software KLSeis is shown in Figure 9.

Mishrif layer: Xmax< 3400m, Zubair layer: Xmax< 5000m, Yamamlayer: Xmax< 5400m and Jurassic layer: Xmax< 6600m. According to the above analysis, the proposed maximum offset is about 5500m.

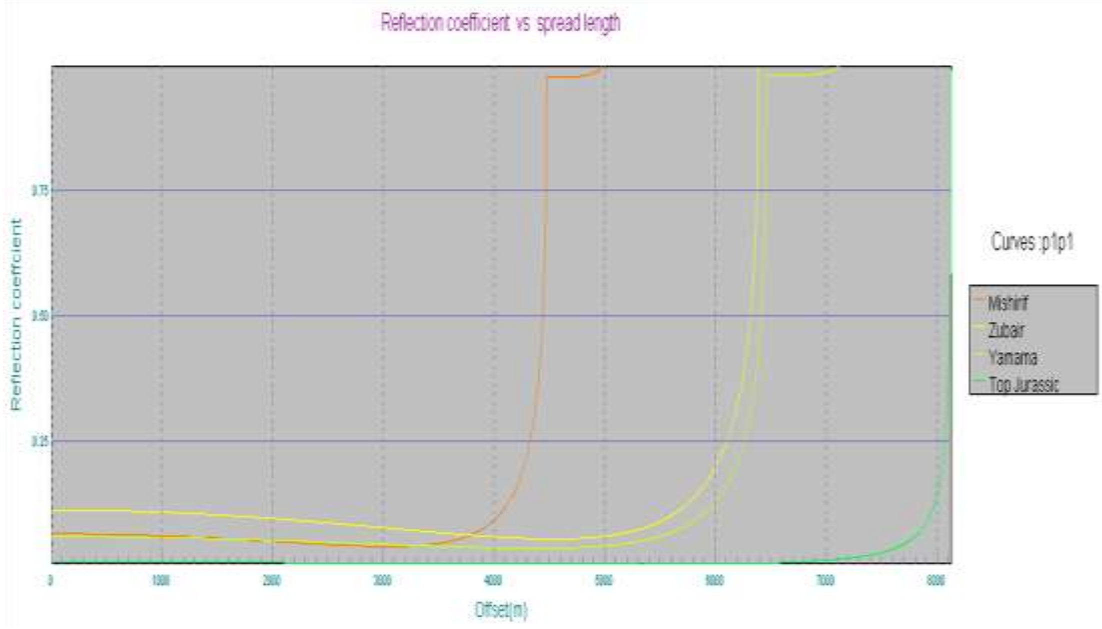

Figure 9-Relation between Reflection coefficient stability and maximum offset.

5. Proposed Geometry

Based on the above, two options can be proposed for the geometry of Mishrif, Zubair, Yamama, Jurassic, Permian Khuff and Pre Khuff Reservoir Zone (Table 4 and Figure 10 a, b, c, d, e and f) for the first option, and Figure 11a, b, c, d, e and f for the second option two.

Table 4- The proposed geometry.

Proposed Geometry	Option1	Option2
Geometry Type	12Lines * 6Shots *216chs	16Lines * 16Shots *208chs
Bin size	25m × 25m	25m × 25m
Receiver line azimuth	132 Degree	132 Degree
Number of receiver lines	12	16
Number of receivers per line	216	224
Active channels	2592	3328
Receiver interval	50m	50m
Receiver line interval	300m	400m
source line azimuth	42 Degree	42 Degree
Source line interval	300m	400m
Source interval	50m	50m
Receiver Line rolls	300m	800m
Shot Density (shots/km^2)	66.67	50
Min Offset	35m	35m
Max. offset	5661m	6178m
Aspect ratio	0.31	0.58
Folds	6×18=108	8×13=104

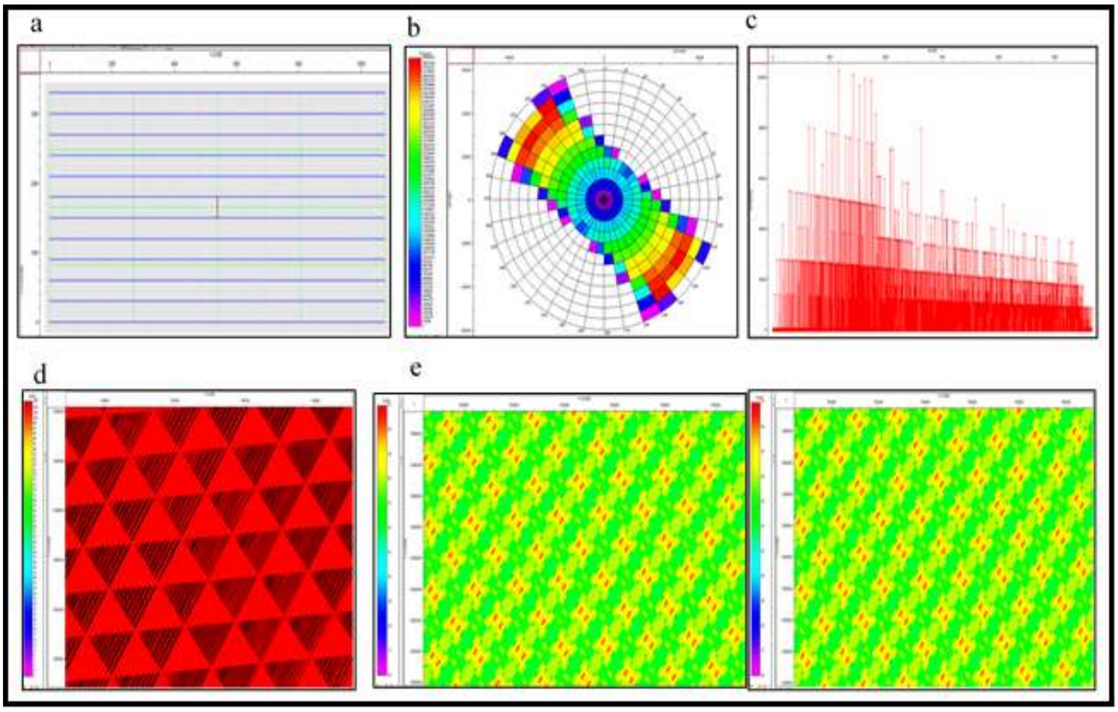

Figure 10-Geometry proposal (Option 1) (a) Unit Template; (b) Rose Map; (c) Offset Bar Graph; (d) Offset Histogram; (e) Fold Distribution (0-4000m, 1; (f) Fold Distribution (0-2000m)

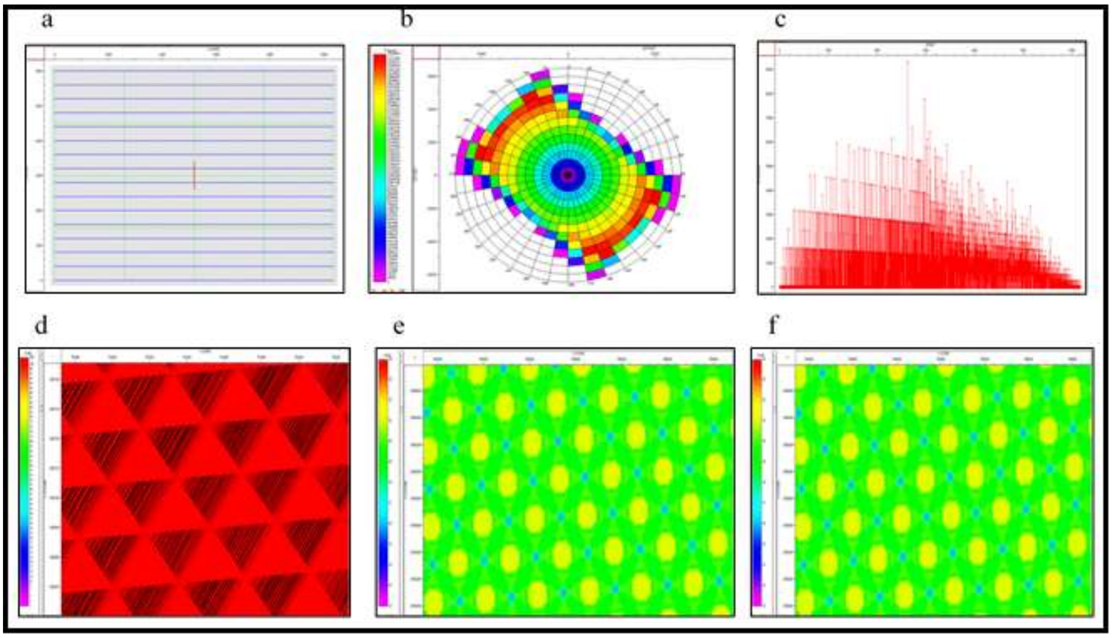

Figure 11-Geometry proposal (Option 2): (a) Unit Template; (b) Rose Map; (c) Offset Bar Graph; (d) Offset Histogram; (e)Fold Distribution (0-2000m; (f) Fold Distribution 0-4000m

6. Source Parameters Proposal

The production of seismic waves is one of the key factors in seismic explorations, so the selection of source parameters will directly affect the seismic data quality. Suitable source parameters are necessary to acquire enough energy return of seismic waves to improve the S/N Ratio of seismic data. Apart from this, it is also needed to widen the frequency band of the seismic wave to improve the resolution of seismic data.

Based on the analysis of the satellite image and the elevation curve in the prospect area, the elevation difference is relatively smaller, and vibroseis is workable in most areas. However, the dynamite source should be used in the area with swamp and water (particularly in the SE part of the block during wet season).

6.1 Vibroseis source

The proposed vibroseis parameters are listed in Table 5:

Table 5- the proposed vibroseis source parameters

Number of vibrators per fleet	4
Vibrator array type	Inline array
Drive level	70%, 75% or 80% (to be tested)
Number of sweeps per VP	1, 2, 3 or 4 (to be tested)
Sweep type	Linear
Sweep frequencies	6 Hz – 84 Hz (to be tested)
Sweep length	10,12,14 or 16 sec (to be tested)

6.2 Dynamite source

If large numbers of vibroseis sources cannot be used due to swamp areas, dynamite is suggested as the energy source in these kinds of areas.

1) Single hole: Hole depth: 9, 12 m or 15 m (to be tested) and Charge size:2 or 3 Kg (to be tested).

2) Array hole:
Charge Depth: 4mX3holes, 6mX2holes or 8mX2holes (to be tested).

Charge size for one hole: 1 or 2 kg (to be tested).
Hole array: Linear.

6.3 Recording Parameters Proposal

Sample Rate: 2ms, Recording Length:6s, Low cut Filter: out, and High cut Filter: 3/4 Nyquist or (187.5) Hz.

6.4 Three-Dimensional Work Volume Statistics

There are two options for the survey. The operational surface area of survey option 1 is about 317 km^2, and option 2 is about 328 km^2.

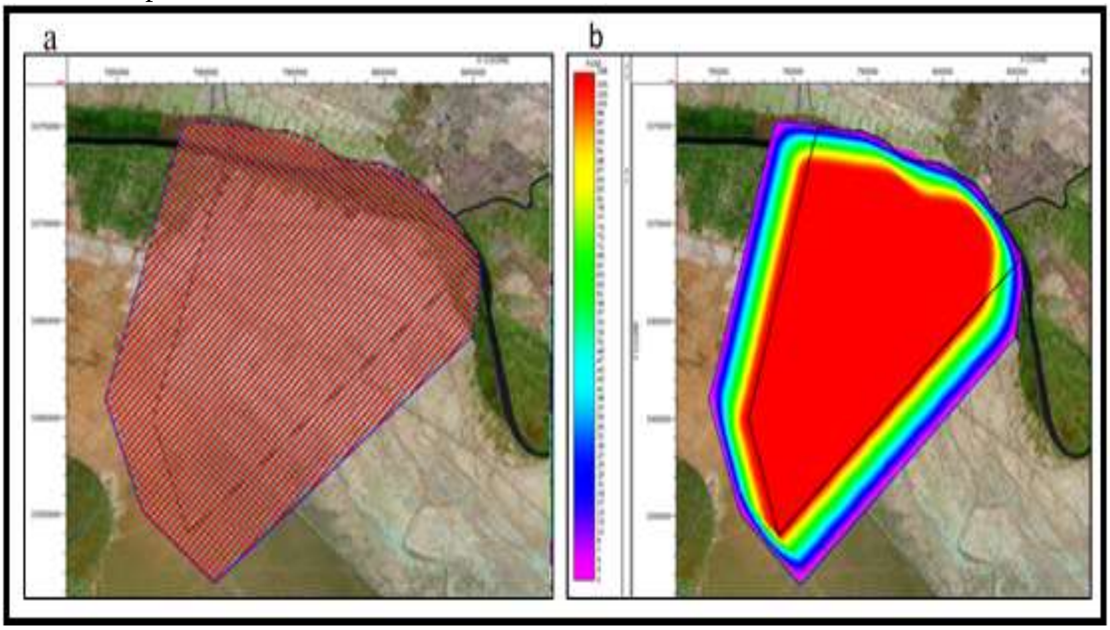

Figure 12-(a) Sources and receivers' distribution map (shots: red); (b) fold distribution map. Note: the survey boundary in the north part of the work has limited the border between Iraq and Iran.

6.5 Low-Velocity Layer Investigation

Because the Siba field structure is low relief, it requires detailed modelling of the low-velocity layer (LVL) and constant estimation to define the structure accurately, so it is necessary to conduct a detailed survey of the LVL in the area.

The operation area is plain, and the surface is flat. The high-velocity top is stable relatively. In order to control the varying weathering depth and velocity, control points are designed as below.

The density of LVL survey points, one point per km^2 for a refraction survey and one point per 10 km^2 for an uphole survey, is proposed.

7. Conclusions

The results of the current study consist of two options for the approved elements in the geometry proposal to make a 3D image of Mishrif, Zubair, Yamamah, Jurassic, Permian Khuff and Pre-Khuff Reservoir Zones, as follows

1. The geometry in option -1 is 12 Lines * 6 Shots * 216 chs and option -2 is 16 Lines * 16 Shots * 208 chs.
2.Receiver Density receivers / km^2 for option 1 and 2 is 66.67 and 50 respectively. 3. Shot Density （shots / km^2） for options 1 and 2 is 66.67 and 50, respectively.
4. Total shots of two options are 21000 and 16200.
5. Total receiving points are 21000 and 16000 for two options 1 and 2, respectively
6. Survey area (km^2) and full fold area (km^2) for the two options are 317, 328 and 198, 198, respectively.

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