Investigation of Subsurface Structures by Using Seismic Refraction Method, Northwestern of Al-Anbar Governorate / Iraq

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Abstract

Seismic refraction survey is conducted along both banks of Euphrates River, northwestern of AL-Anbar governorate in order to investigate the subsurface structures at the study area. Four main layers are delineated from the results of interpretation to the seismic data. The first layer represents surface layer which corresponding to quaternary deposits , the ranges of velocity and thickness to the first layer are (600m/sec-950m/sec) and (2.26m-7.4m) respectively. The second layer corresponding to Euphrates Formation with ranges of velocity and thickness between (1400 m/sec -2000 m/sec) and (6.2 m-21.2 m) respectively. Third layer corresponding to Anah Formation with velocity and thickness ranges between (2400 m/sec - 3000 m/sec) and (20.6m-40.4m) respectively. Fourth layer corresponding to Baba Formation it has velocity range between (3333m/sec- 4000m/sec). The area at the right bank of Euphrates River is characterized by complex geological situation. Two faults are recognized on the right bank of Euphrates River (F1 and F2), both of them are normal. The first one is located at a distance of 230 m from the river bank and the second is located at a distance of 575m from the river bank. The area at the left bank of the Euphrates refer is characterized by horizontal layers and there is no evidence of any subsurface faults in this part of the study area.

Key Words:- Seismic refraction, subsurface structure , Normal Faults , Anah Formation .

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التحري عن التراكيب التحت سطحية باستخدام الطريقة الزلزالية الانكسارية شمال غرب محافظة الانبار / العراق

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الملخص

اجري مسح زلزالي انكساري على جانبي نهر الفرات شمال غرب مدينة الانبار للتحري عن التراكيب التحت سطحية في منطقة الدراسة. أظهرت نتائج التفسير للبيانات الزلزالية أربع طبقات رئيسية. الطبقة الأولى تمثل الطبقة السطحية وتشمل على ترسبات العصر الرباعي حيث تراوح مدى السرعة الزلزالية لهذه الطبقة بين(600م/ثا-900م/ثا) والسمك بين (2.26م- 7.4م) الطبقة الثانية تكافئ تكوين الفرات الجيري الذي ظهرت بمدى سرعة زلزالية بين(1400م/ثا -2000م/ثا) وبسماكة تتراوح بين(6.2م-21.2 م). الطبقة الثالثة تشتمل على تكوين عانة الذي ظهرت بسرع زلزالية تتراوح بين(2400م/ثا -3000م/ثا) وبسماكة تراوحت بين(20.6م- 40.4 م) , اما الطبقة الرابعة التي تشتمل على تكوين بابا فظهرت بسرع زلزالية تراوحت بين (3333م/ثا-4000م/ثا). المنطقة على الجانب الايمن لنهر دجلة امتازت بوضع جيولوجي معقد حيث تم تمييز فالقين اعتياديين يبعد الأول مسافة 230 م عن نهر الفرات والثاني يبعد عن النهر بمسافة 575 م ويمتدان الى نهاية عمق التحري, بينما امتازت المنطقة في الجانب الايسر لنهر الفرات بتركيبها البسيط ولم يظهر اي دليل على تواجد فوالق تحت سطحية في هذا الجانب.

الكلمات المفتاحية:- الزلزالية الانكسارية ,تراكيب تحت السطح , فوالق اعتيادية , تكوين عانة

Introduction

Seismic surveys are widely used around the world to produce a detailed image of the geology beneath the earth's surface. The seismic refraction method is one of the seismic techniques which is frequently used to determine the characteristics of soils and rocks [1] and [2]. Seismic refraction finds application in the determination of rock competence for engineering application, depth to bedrock, groundwater exploration, crustal structure and tectonics [3]; [4]; [5] and [6].

The seismic refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between subsurface layers of different velocity [2]. The seismic signal is introduced into the subsurface via a shot point using explosives, hammer blow, dropped weight or an elastic wave generator [7].

The energy generated either travels directly through the upper layer (direct arrivals), or travel down through the various layers before returning to the surface (refracted arrivals). The energy is then detected on surface at a series of receivers called geophones spaced at regular intervals [8]. After a certain distance from the shot point, known as the cross over distance, the refracted signal is observed as a first arrival signal at the geophones (arriving before the direct arrival). Both compressional waves (P-waves) which provide depth information of interfaces and Shear waves (S-waves) which provide additional data about engineering properties of the subsurface media can be used in the seismic refraction method [2] and [9].

The seismic method relies on the tendency of acoustic velocities to increase with depth, which sometimes makes it insensitive to low velocity layers in the subsurface. Based on the analysis of the field data, the seismic surveyor draws a profile showing the thickness of the subsurface and a good idea of what materials they consist of [2]; [10]; [7]; [5]and [9]. Seismic refraction survey uses the process of critical refraction to infer interface depths and layer velocities. The data are usually are plotted as time –distance curves and then presented as cross sectional plots representing P-wave path, velocities and depths to various interfaces. The aim of using seismic refraction survey in the current study is to get a better view of the subsurface layering and structures in both lateral and vertical directions.

Location and Geological Setting of The Study Area.

The study area is located in the northwestern part of Al-Anbar governorate western of Iraq between latitudes34.43º-34.46º N and longitude 41.71º- 41.73º E, along both banks of Euphrates river (figure-1-). The topography is irregular , where is the area at the left bank of the river being flat almost with an average height about 154m above sea level, while at the right bank of the river the maximum highest is 198m at the northeastern direction and the minimum height is 142m at the southwestern direction . Four boreholes are located a few

meters away from the study area(figure-2-). According to these boreholes, three rock groups are characterized at the study area, these are , Oligocene group, Miocene group and quaternary deposits. The following is a brief description of the geological Formations from the oldest to the youngest:-

1- Oligocene group:- consists of two rock units, these are from oldest to youngest :-
   - Baba Formation (Middle Oligocene):-This Formation composed of chalky fossiliferous limestone[11].
   - Anah Formation (Upper Oligocene):- This Formation consists of white or grey dolomitlzsd and recrystallized limestones, massive in the lower part and thinner

     bedded upwards. Dolomitization is strongest in the upper parts.
2- Lower Miocene group:- This group represented by Euphrates Formation. This Formation is divided into two members [11], [12] :-
   - The lower member :- consists of mainly of basal conglomerate , gravels followed by layers of limestone that contains fossils.
   - The upper member:- consist of sequence of brecciated rock unit, chalky limestone , dolomite with horizontal lenses and layer of green shale.
3- Quaternary deposits:- Different types of Quaternary deposits are developed in the studied area. Quaternary sediments forms a discontinuous cover represented by River terraces, sand, gravel, conglomerate in addition to the river shoulders and valleys shoulders.

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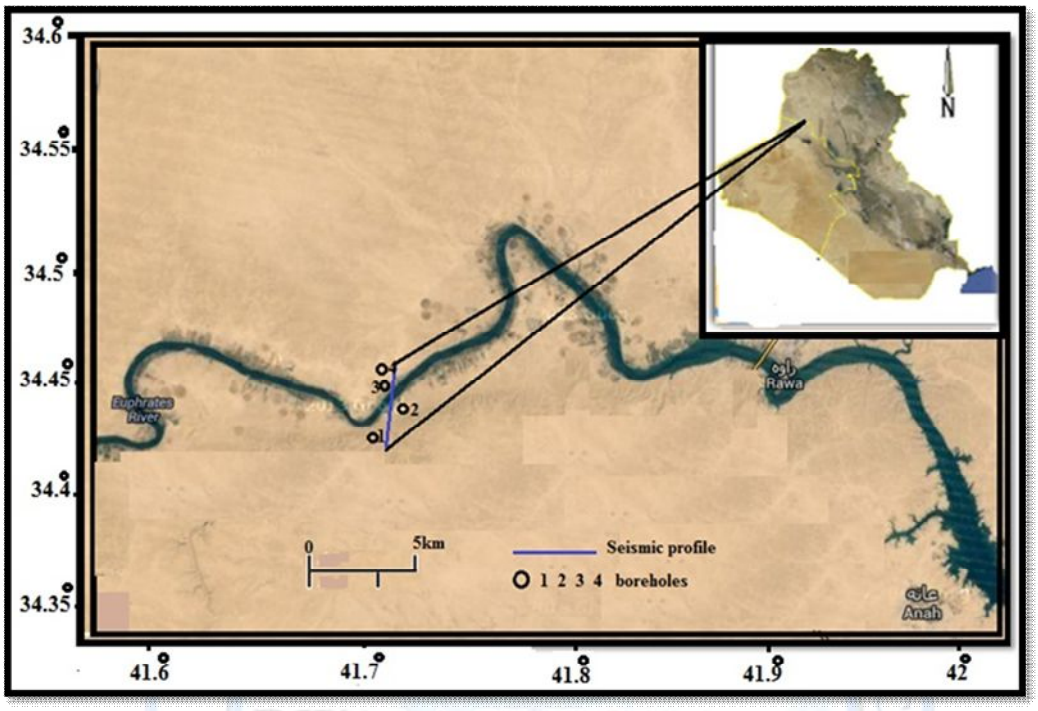

Figure (1) Location maps of the study area.

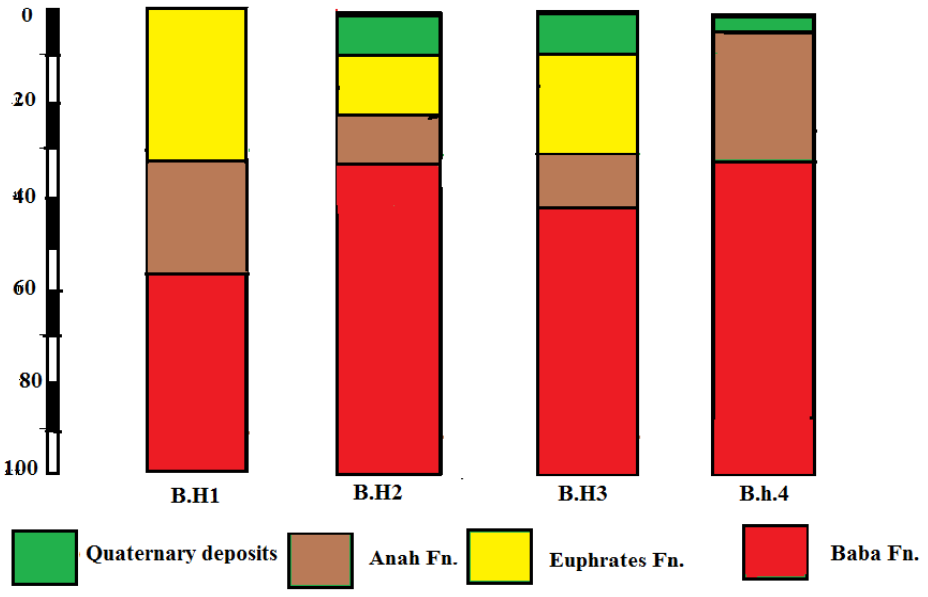

Figure (2) Lithostratigraphic distribution in available boreholes at the study area

Methodology

Data Acquisition

Seismic refraction survey is carried out by using ABEM TERRALOC MK3 seismograph. The measurements are taken along both banks of Euphrates River (figure -1-c). The total length of the seismic survey line is 2970m, 900m on the right bank and 2070m on the left bank. Twelve seismic spreads are laid on profile, three spreads on the right bank and nine on the left bank. Each geophone spread consisted of 24 geophones placed 10m apart. For each spread, the number of shots are from 5-7 shots and located at normal, reverse, center and offsets of 100m 200m at both sides of the spreads (figure-3-). A sledge hammer of 10kg in weight is used as seismic source for short distance shots (Normal, Center and Reverse shots), and explosive source with 200gm charge of dynamite was used for offset distance 100m-200m from both ends of spreads. The instrument is triggered by two different ways ,these are by using trigger geophone near the shot point and by using the break switch at far shots. In order to improve the signal to noise ratio, each shot is stacked 5-10 times , and low cut frequency of (10-34 Hz) and high cut frequency of (20-100 Hz) are done to remove the unwanted signals and to improve the signal to noise ratio.

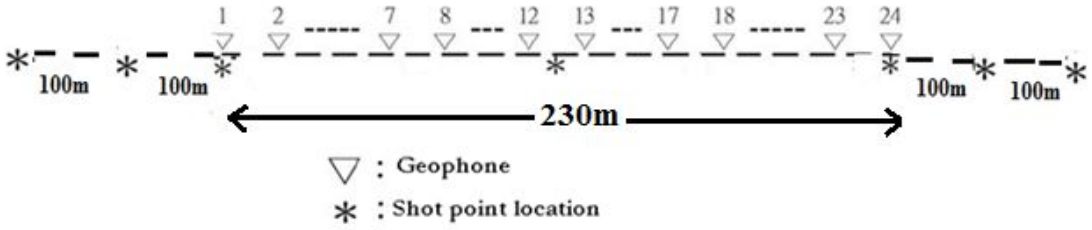

Figure (3) Geophones distribution and shot points locations

Data Interpretation

The first step in processing and interpreting of refraction seismic data is to pick the first arrival times of the signal, called first break picking. A plot is then made showing the arrival times against the distance between the geophones. This is called a time-distance graph (Figure

4). The time-distance graphs are interpreted in terms of layer velocities and depth to refraction boundaries by applying least square and intercept time method respectively. The values of velocities and depths are used to construct seismic section at the study area which are finally evaluated in term of geological sections.

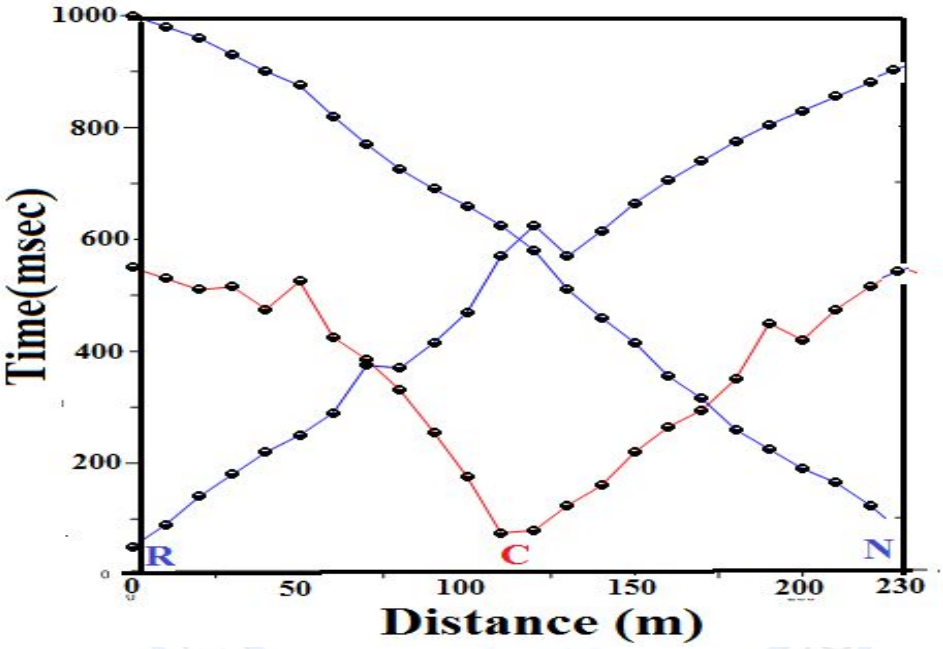

Figure (4) Time distance graph for spread 2 at right bank area with out offsets

Results And Discussion

Seismic cross sections of the survey line for both right and left banks of Euphrates river (Figures 5 and 6) show, that the study area generally consists of four main layers, the ranges of velocities and thickness of these layers are listed in table (1). These layers from top to bottom consist to:-

1. A surface layer corresponding to quaternary deposits .
2. Second layer corresponds to Euphrates Formation. This layer appear at the surface in some places at the right bank of the river.

3. Third layer corresponding to Anah Formation

4. fourth layer corresponding to Baba Formation

Two faults are shown on the section at the right banks of the Euphrates River(F1 and F2), both of them are normal faults. The first one is located at a distance of 230 m from the river bank and the second is located at a distance of 575m from the river bank. These faults are the main reasons that make the second layer disappear and rise as a surface layer in some parts at the study area. The area between these faults seems as horst by influence of the faults. The area at the left bank of the Euphrates River is characterized by horizontal layers and there is no evidence of any subsurface faults in this part of the study area.

Table(1) range of velocity and thickness of different layers

Layer velocity (m/sec)	Range of velocity (m/sec)	Layer thickness(m)	Range of thickness(m)
V1	600-950	T_1	2.26-7.4
V2	1400- 2000	T_2	6.2- 21.2
V3	2400-3000	T_3	20.6 -40.4
V4	3333-4000	T_4	-

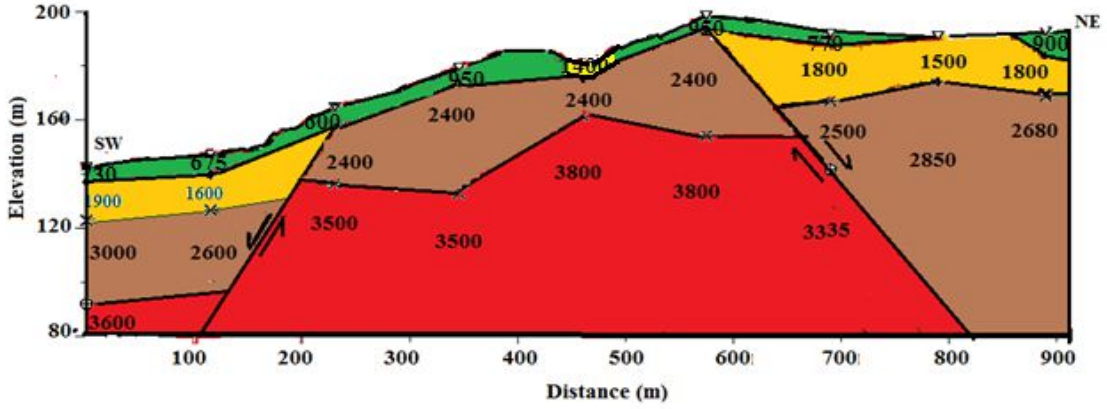

Figure (5) seismic section at the right bank of Euphrates River

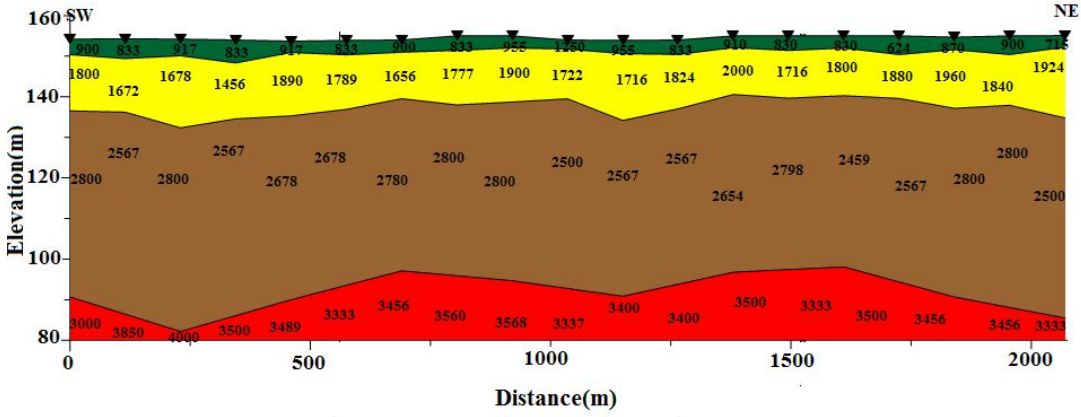

Figure (6) Seismic section at the left bank of Euphrates river

Conclusion

Seismic refraction method is used to delineate the subsurface structure at the study area . Four main layers are delineated from the results of interpretation, the first layer represents surface layer which corresponding to quaternary deposits , the second layer corresponding to Euphrates Formation , third layer corresponding to Anah Formation ,and fourth layer corresponding to Baba Formation . Two faults are recognized on the right bank of Euphrates River (F1 and F2), both are normal faults. The area between these faults seems as horst by influence of these faults. These faults extending at the interfaces between second and third layer and between third and fourth layer, these faults are the main reasons that make the second layer disappear in some parts at the study area. The area at the left bank of the Euphrates refer is characterized by horizontal layers and there is no evidence of any subsurface faults in this part of the study area.

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