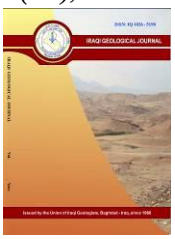
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Geotechnical Characterization Using 2D and 3D Seismic Refraction Method for a Site in Sulaimani City, NE Iraq

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Abstract

The number of project has been failures and increasing recently due to weak zones in the building's foundation and rocks. So, Geophysical investigations related to the site foundations before the construction stage are vital to avoid the danger of future collapse of engineering structures. Therefore, it was decided to inspect the location of one of the proposed engineering sites by achieving the seismic refraction surveying with the aim of detecting the possible weakness zones for the site foundation rocks. A Geode instrument is used to acquire data which then surveying data acquisition was achieved for parallel traverses with 4m spacing between each one. Thus, 10 lines with a length of 115 m each were taken with a geophone spacing of 5 m apart. Then, the data is processed with Pickwin software, which is used to pick and denoise data. After that, the initial model was created with Plotrefa software and the inversion was converted to a layer model. Then, a 3D model of the studied site is created by using Zond software. Finally, the velocity model of the study site was built for both Vp and Vs results. As a result, three different layers with velocity values ranging between 300-4000 m/s, thicknesses of 8, 6 and 16 m belong to the top soil, weathered layer and Tanjero Formation of sandstone or marl were determined. Many Faults were identified as structures affecting the project construction which appearing in all studied profiles, located at a distance of 60 m and at depths ranging from 8 to 14 m in a northwesterly direction. Petrophysical, geotechnical, and elastic parameters were calculated from the Vp and Vs data. Finally, the studied layers were found to be weak, incompetent or fairly competent.

Keywords: Seismic refraction; Geotechnical evaluation; Seismic waves; Sulaimani; NE Iraq

1. Introduction

The number of failures is increasing in the construction of structures such as buildings, dams, bridges and many other structures due to the lack of information regarding the subsurface geological and engineering reality, which includes foundations in particular. Therefore, a preliminary investigation for any site is important for projects using geophysical explorations. One of the most important geophysical methods that used for prospecting and investigation is the seismic refraction which is the fastest and least expensive methods than laboratory tests or well drilling (Tezcan et al., 2009). The seismic method can provide more detail information about the bedrock structure, velocity distribution, and depth of underlying layers (Azwin et al., 2013).

There are many researches that worked inthe field of seismic refraction for geotechnical and site characterization. (Baban et al., 2022) as one deals with seismic refraction tomography and geotechnical parameters to assess the Chaq-Chaq dam failure in NW of Sulaimani city. Shazly et al. (2023) also

performed this method in conjugation with other geophysical methods to evaluate geotechnical properties at Al-Galala Plateau, Egypt. Al-Heety and Al-Saigh (2014) used the seismic method for geotechnical evaluation of the soil at the teaching hospital project, Mosul University (Khorshid et al., 2014) carried out a geotechnical evaluation of the soils in the Tikrit University. Sarkar et al. (2021) carried out two geophysical methods as near surface seimic refraction and MASW for site characterization Phuentsholing, Bhutan Himalaya. Others used this method in detection of the faults, (Ostrowski et al., 2016; Hiltunen and Cramer, 2008) in karst terranes detection in landfill studyand (Asamoah et al., 2018) for evaluation the geotechnical parameters and site characteristics determination.However, In Kurdistan regionthere are very few researchers who use this method (Baban et al., 2022). However, there are many other geophysical methods used for site investigation used the electrical resistivity method for different engineering purposes. The the gravity and magnetic methods was carried out in the Kurdistan region. Al-Manmi et al. (2020) used the geophysical method for hydrogeochemical investigation and for estimating aquifer hydraulic parameters.

The main objectives of this research included geotechnical identifying and evaluation of the foundation rocks at a construction site for a future residential and tourism project in the Bakrjo area, Sulaimani City, NE Iraq. The survey also included identifying rock strata, its characteristics, and detecting weak structural zones.

2. Location of the Studied Area

The current study site is located in NE of Iraq, Kurdistan Region, Sulaimani City, Bakrajo area at 35°33'36.02"N and 45°21'55.92"E, as shown in Fig. 1. The surveyed area is about 7000 m^2 and the which covered by Ten profiles trending in NW-SE direction which are parallel to the general strike of the structurs.

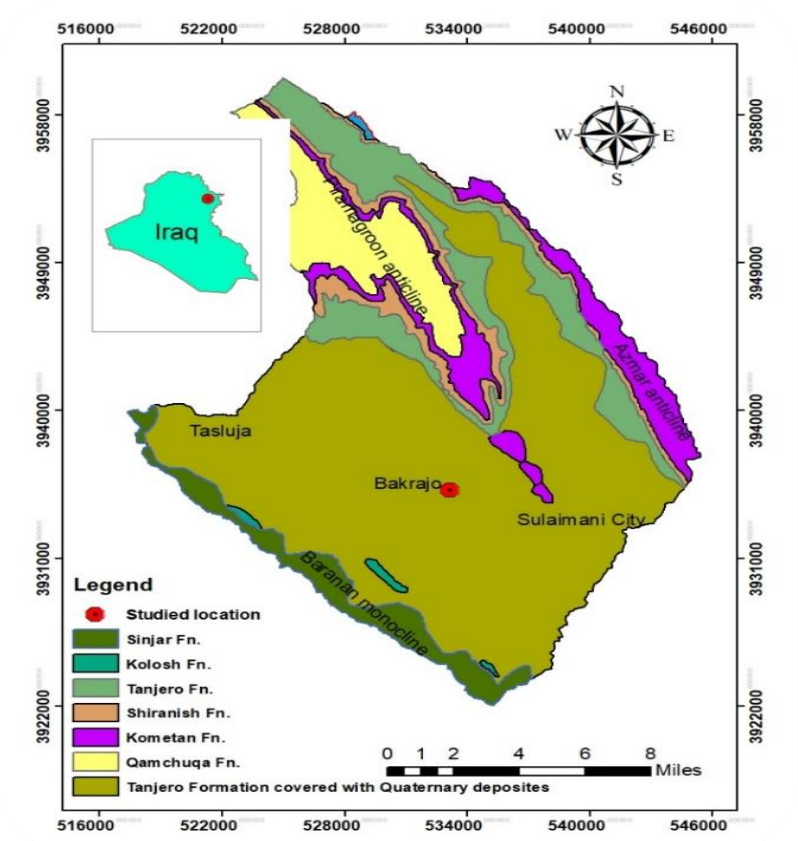


Fig. 1. Location of the studied site with surrounding lithology

3. Geology and Tectonics of the Studied Area

In terms of plate tectonics, the studied site is located within the high folded zone region (Jassim and Goff, 2006). Geologically, the region around the studied site consists of several Formations, where they are arranged from the oldest to the newest one as follows: Kometan, Shiranish, Tanjero, Kolosh and Sinjar Formations, whereas the studied site was located on the Tanjero Formation and covered with the Quaternary deposites that outcrped in some places, as shown in Fig. 1, 2 and 3. Each of these Formation consists of different lithologies such as limestone, sandstone, marl, conglomerate, shale and massive limestone. The Kometan Formation comprises of light grey, thin bedded limestone, locally silicified with chert concentrations in some beds with a glauconitic bed at the base. It is widespread in central, north and northeast of Iraq. The Shiranish Formation comprises thin bedded argillaceous limestone (locally dolomitic) overlained by blue pelagic marle. The Tanjero Formation comprises two divisions, the lower division comprises pelagic marl and occasional beds of argillaceous limestone with siltstone beds in the upper part, while the upper division comprises silty marl, sandstone, conglomerates and sandy or silty organic detrital limestone. The Kolosh Formation, comprises, from the top, the limestone and marls, limestone and shales, red shales and sandstones, blue shales and green sand. The Sinjar Formation, however, comprises limestone of algal reef, lagoonal miliolid and nummulitic shaol facies (Jassim and Goff, 2006).

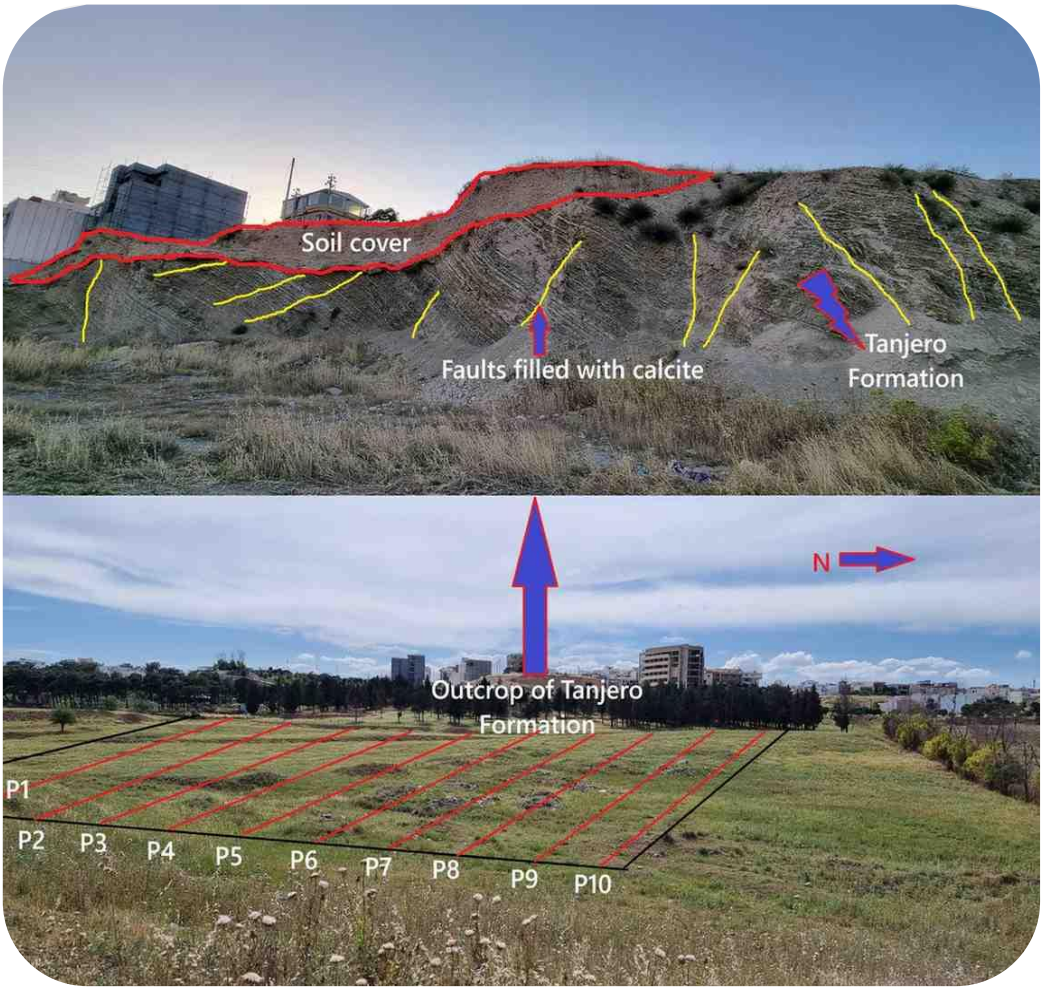


Fig. 2. Outcrop of the Tanjero Formation at the studied site

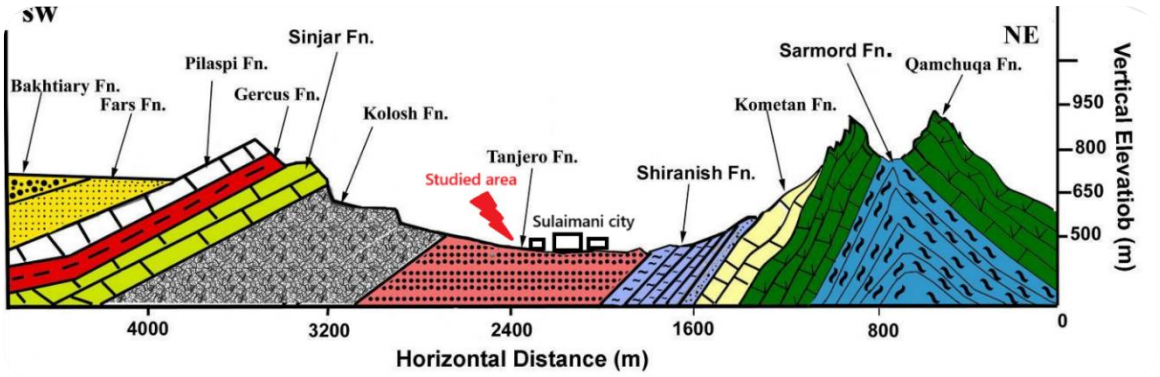


Fig. 3. Geological cross section of the studied area and Sulaimani City

4. Materials and Methods

The geophysical method which be used in this study is the seismic refraction method. A Geodeseismograph instrument mode was used to record the data which consists of Geodecontrol and data recording system, 24 geophones, connecting cable, sledgehammer 10LB and battery 12V, as shown in Figs 4 and 5. The Refracted P waves and S waves were measured on 10 parallel lines (profiles) oriented in NW-SE, nearly parallel to the strikes of the structure available in the studied area with 4 m spacing between them, which is believed that it is suitable for geotechnical investigations, as shown in (Fig. 6). Each profile having 3shot points on both ends located at -5m, 120m and in the middle at 57.5m as well, 3 stacking is also usedwhich is suitable for getting a good signal and reducing noise.The distance between the geophones was 5m, making the line (profile) length 115 m. Another acquisition parameter namely, the number of stacking 3, sampling interval 62.5msec, record length 0.25 sec, trigger extension cable 92m and number of iterations 10 also be determined. The data was processed and interpreted using the program of Pickwin, Plotrefa and Zond softwares ("ZondST2d — 2D seismic data processing and interpretation software," 2001-2017). However, the data was filtered and the noise be deleted using the programof Pickwin.Picking was done for the first arrivals with the same program, which then saved and prepared for the program of Plotrefa.The initial model was then created, inverted and extracted as layered model. All Parameters as, Poisson's ratio (σ), Elastic modulus (E), Shear (Rigidity) modulus (μ), Bulk modulus (B), and Compressibility (K) were determined after the computation of Vp and Vs (El Sharawy and Nabawy, 2016; Nabawy and El Sharawy, 2015; Telford et al., 1990). Finally, a 3D image of the investigated site was created using Zond software.



Fig. 4. The data collection in the field site



Fig. 5. Main cable, Geophones, Hammar, striking plate and Sensor

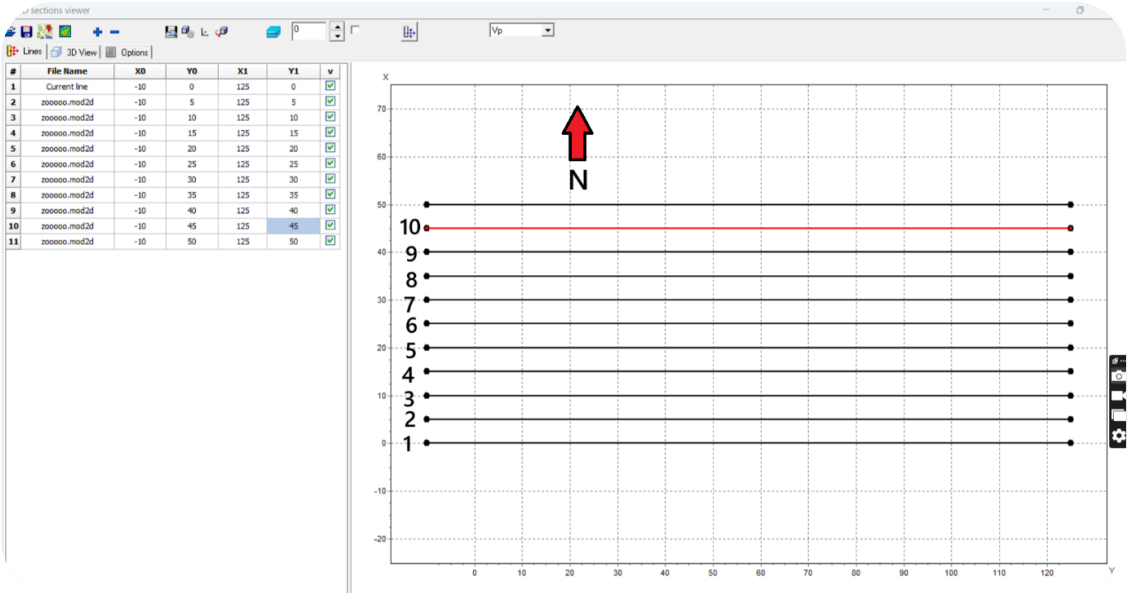


Fig. 6. Sketch illustrating location of the profiles relative to the north direction

5. Data Processing

The first step for processing the field data is to filter them from the noise in order to recognize the first arrivals of the P and S-waves, as shown in Fig. 7. Well, picking is done for the record and then prepared and saved for the Plotrefa program, as shown in Fig. 8, where the data can be enhanced again. It should be noted that the S-waves can be identified from the refraction sections in which its amplitude is larger than P-waves in one hand and its arrival time is twice than the P-waves on the other hand, therefore it can be determined from the Seisimager (SW) softwares, as shown in Fig. 9. However, the initial velocity model can be created with the same program and the RMS % errors between observed and the synthetic data which then calculated, inverted automatically and finally converted into layer model. In this stage, a 3D image was created for all 2D profiles by using Zond software ("ZondST2d — 2D seismic data processing and interpretation software," 2017), as shown in Figs. 10 and 11 respectively. Finally, where Vp and Vs are determined, then all parameters including density, porosity, void ratio, Poisson's ratio, Rigidity, Young modulus, Bulk modulus, Concentration index Ci, Stress index Si, Material index Mi and Ultimate bearing capacity can be calculated.

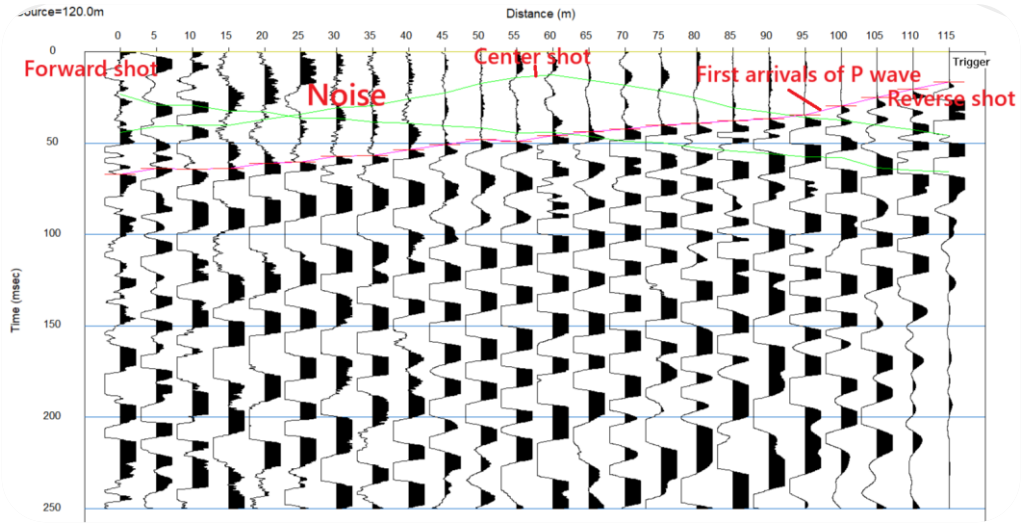


Fig. 7. Seismic refraction section in reverse shot and appended with forward and center shots

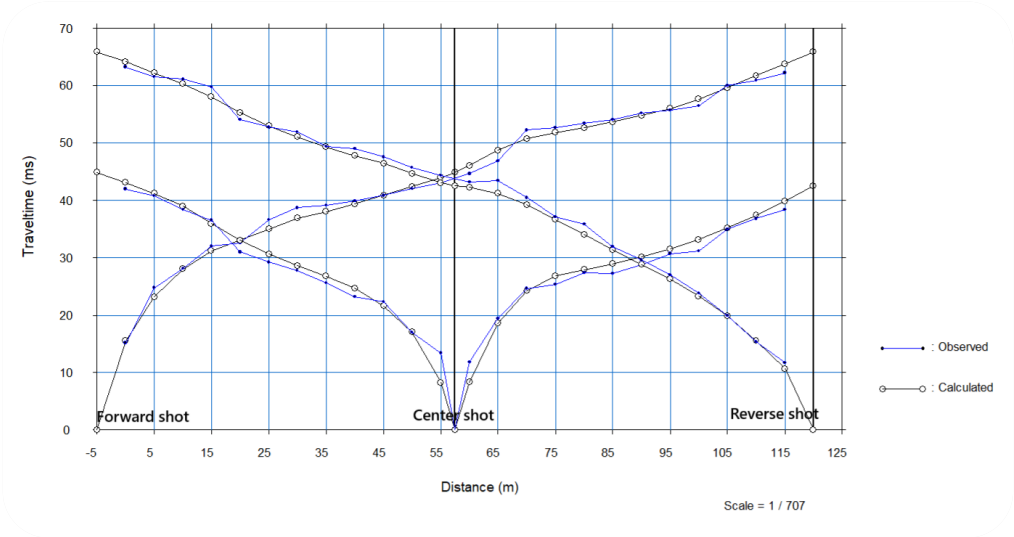


Fig. 8. Observed and calculated travel time for P-waves

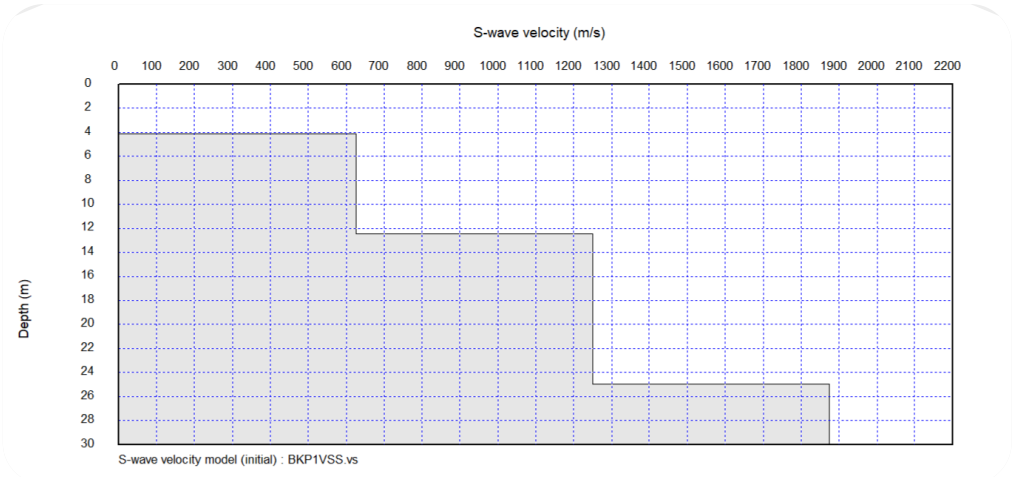


Fig. 9. S-wave velocity modeling using Seisimager software

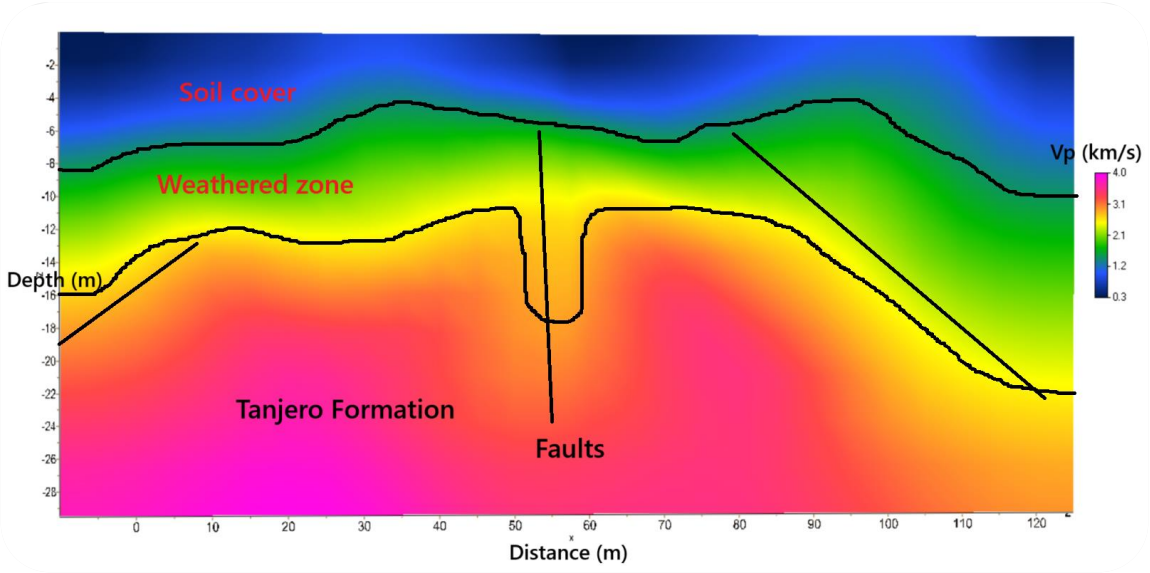


Fig. 10. 2D velocity modeling of Vp

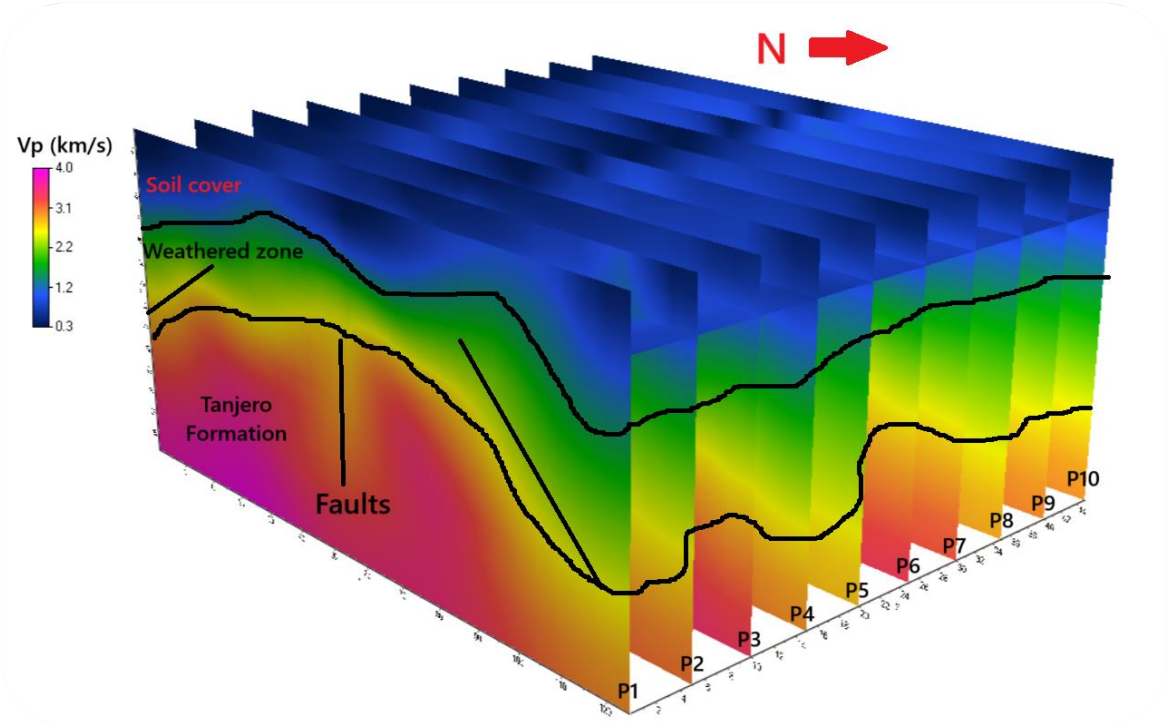


Fig. 11. 3D velocity modeling of Vp

6. Interpretation and Discussion of the Results

The data are interpreted in terms of Vp andVs, number of layers, lithology as, depth, thickness, presence of faults and other geological features if existed, as shown in Tables 1 and 2 and correlated with bore hole data, that is created depending on a well close to profile 9, other wells close to the studied site and outcrops, as shown in (Fig. 12). In general, all profiles revealed three layers according to the velocity of the primary waves, as shown in (Fig. 13). However, the results of these profiles can be described and given as the following:

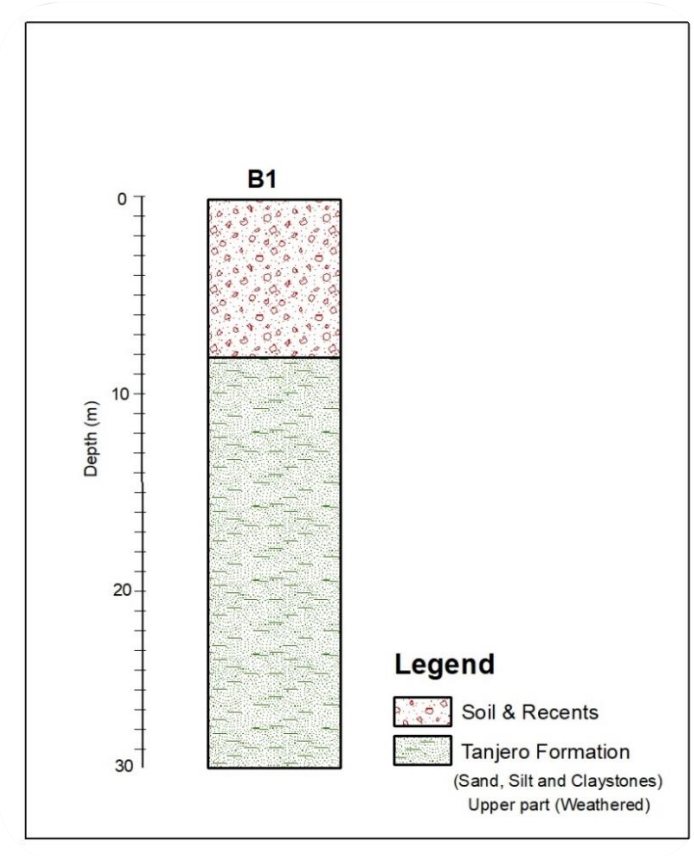


Fig. 12. Bore hole (B1) data that located close to the profile 9

The first profile appeared three layer (zones): the first layer is represnented by the top soil, the second represented by the weathered zone while the third layer is represented by the Tanjero Formation.The top soil layer is about 4-8m thick, Vp 536m/s, Vs 140.5m/s and the second layer is the weathered zone located at depth of 8-14m with Vp 2750m/s, Vs 905.5m/s. However, the third layer is represented by the Tanjero Formation located at depth ranged from 14-30m with Vp 4748m/s and Vs 1904.6m/s. Two faults were recognized, the first one located at distance of 60mfrom the bigging of the profile in NS direction with depth of 10m,whereas the second one is at distance of 100m and extended to the depth. Both faults are located in the Tanjero Formation. The second profile shows even three layer case, the 1stis the top soil consists recent deposits with thickness of about 0-8m, Vp 601.5m/s and Vs 158m/s. the 2ndlayer is represented by the weathered zone with 8-14m thickness and Vp 2395.6m/s, Vs 1340.3m/s,whereas the 3rd layer is represented by the Tanjero Formation with thickness of 14-30m, Vp 3477m/s and Vs 2400m/s. Two faults are also displayed in this profile as in the previous one in their location and characteristic.

The third profile even show three case, the first layer is top soil with thickness of 0-9m, Vp 411.66m/s and Vs 173m/s. The second one is the weathered zone with thickness of about 9-14m, Vp 2507.3m/s and Vs 827.5m/s, whereas the thickness of the Tanjero Formation is found to be ranged between 14-30 m, Vp 3605.3 m/s and Vs 1667.3m/s. Two faults are also displayed, which continuing here at the beginning, 60m and about a distance of 100m, as shown in Fig. 14.

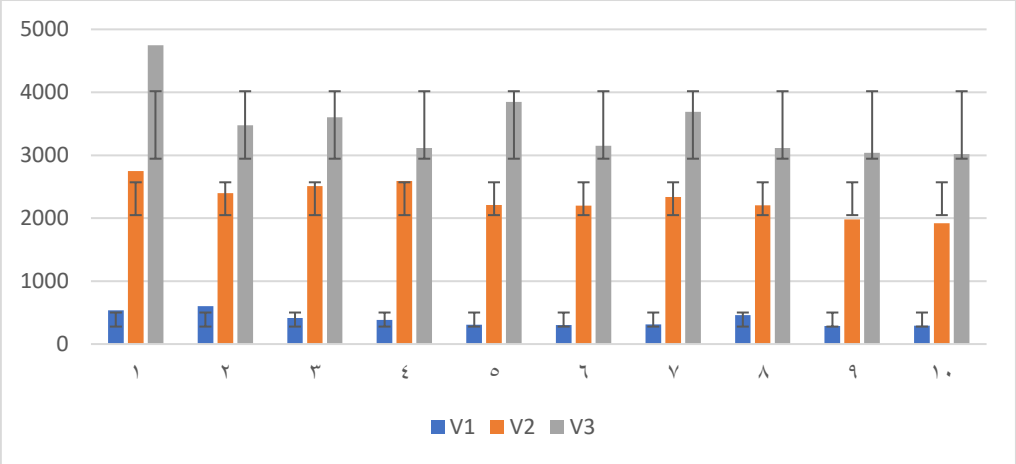


Fig. 13. Histogram of Vp layers for all tenth profiles

Table 1. No. of layers, depth, thickness, lithology and Formation for all profiles

Profiles	Layers	Depth, m	Thickness, m	Lithology	Formation
1	1	0	4-8	Soil cover	
	2	4-8	6-2	Weathered layer	
	3	12-14	16-18	Snadstone and Marl	Tanjero Formation
2	1	0	6-9	Soil cover	
	2	6-9	5	Weathered layer	
	3	11-14	16-19	Snadstone and Marl	Tanjero Formation
3	1	0	6-8	Soil cover	
	2	6-8	6	Weathered layer	
	3	12-14	16-18	Snadstone and Marl	Tanjero Formation
4	1	0	6-8	Soil cover	
	2	6-8	3-10	Weathered layer	
	3	9-18	12-21	Snadstone and Marl	Tanjero Formation
5	1	0	4-8	Soil cover	
	2	4-8	6-10	Weathered layer	
	3	10-18	12-20	Snadstone and Marl	Tanjero Formation
6	1	0	7-8	Soil cover	
	2	7-8	4-6	Weathered layer	
	3	11-14	16-19	Snadstone and Marl	Tanjero Formation
7	1	0	7-8	Soil cover	
	2	7-8	5-6	Weathered layer	
	3	12-14	16-18	Snadstone and Marl	Tanjero Formation
8	1	0	6-8	Soil cover	
	2	6-8	4-8	Weathered layer	
	3	10-16	14-20	Snadstone and Marl	Tanjero Formation
9	1	0	6-9	Soil cover	
	2	6-9	4-6	Weathered layer	
	3	10-15	15-20	Snadstone and Marl	Tanjero Formation
10	1	0	6-10	Soil cover	
	2	6-10	6	Weathered layer	
	3	12-16	14-18	Snadstone and Marl	Tanjero Formation

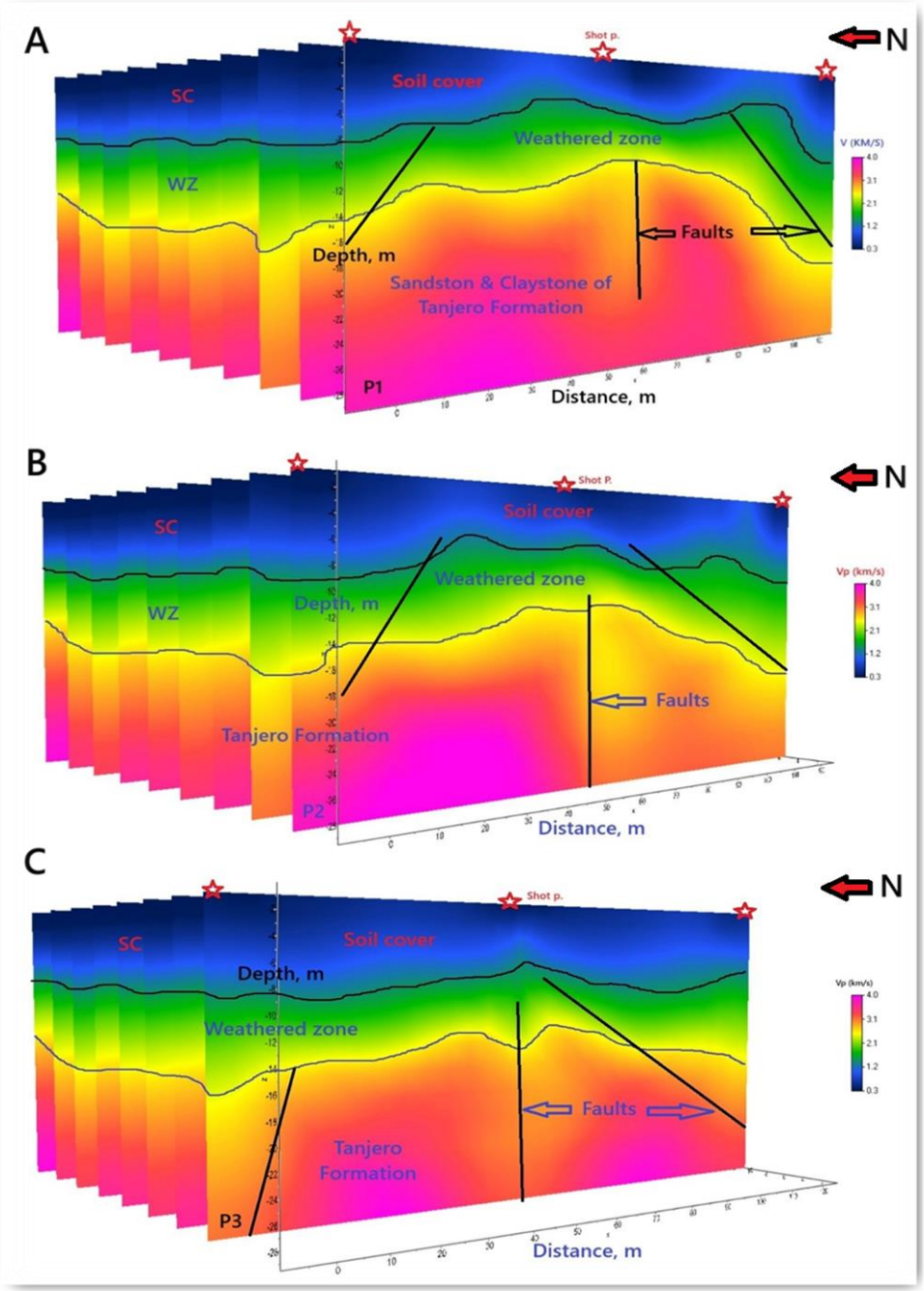


Fig. 14. 3D refraction blocks, A. Profile one. B. Profile two. C. Profile three

Three layers case are also appeared in the fourth profile, where the 1st layer is characterized by top soil with thickness of 0-6m, Vp 381.5m/s and Vs 152.5m/s., the 2nd layer is characterized by the weathered zone with thickness of 6-11m, Vp 2590m/s and Vs 1260.6m/s. The thickness of the third layer is 11-30m, Vp 3115.5m/s and Vs 1820.3m/s, represented by the Tanjero Formation. Faults can also be seen in this profile, in distance 60m and 100m, respectively. In the fifth profile, the top soil is the 1st layer with thickness of 0-5m, Vp of 305m/s and Vs of 154m/s. The second layer of weathered zone with thickness ranged between 5-11m, Vp 2207m/s and Vs 1140.4m/s. The Tanjero Formation which appereaed as the 3rd layer having a thickness ranged between 11-30m, Vp 3849.5m/s and Vs 1475.5m/s. Both faults were displayed and confirmed their location in this profile.

The sixth profile show even three layer, the top soil as 1st layer with thickness about 0-6m, Vp 303m/s, Vs 150m/s, the second layer which represented by the weathered zone but hard slightly with

thickness 6-12m, Vp 2198.3m/s, Vs 882.33m/s. The third layer consists of sandstone or marlstone which is belong to the Tanjero Formationhaving a thickness of 12-30m, Vp 3151.5m/s, Vs 1155m/s. The previous mentioned faults can also be seen clearly in this profile, as shown in Fig. 15.

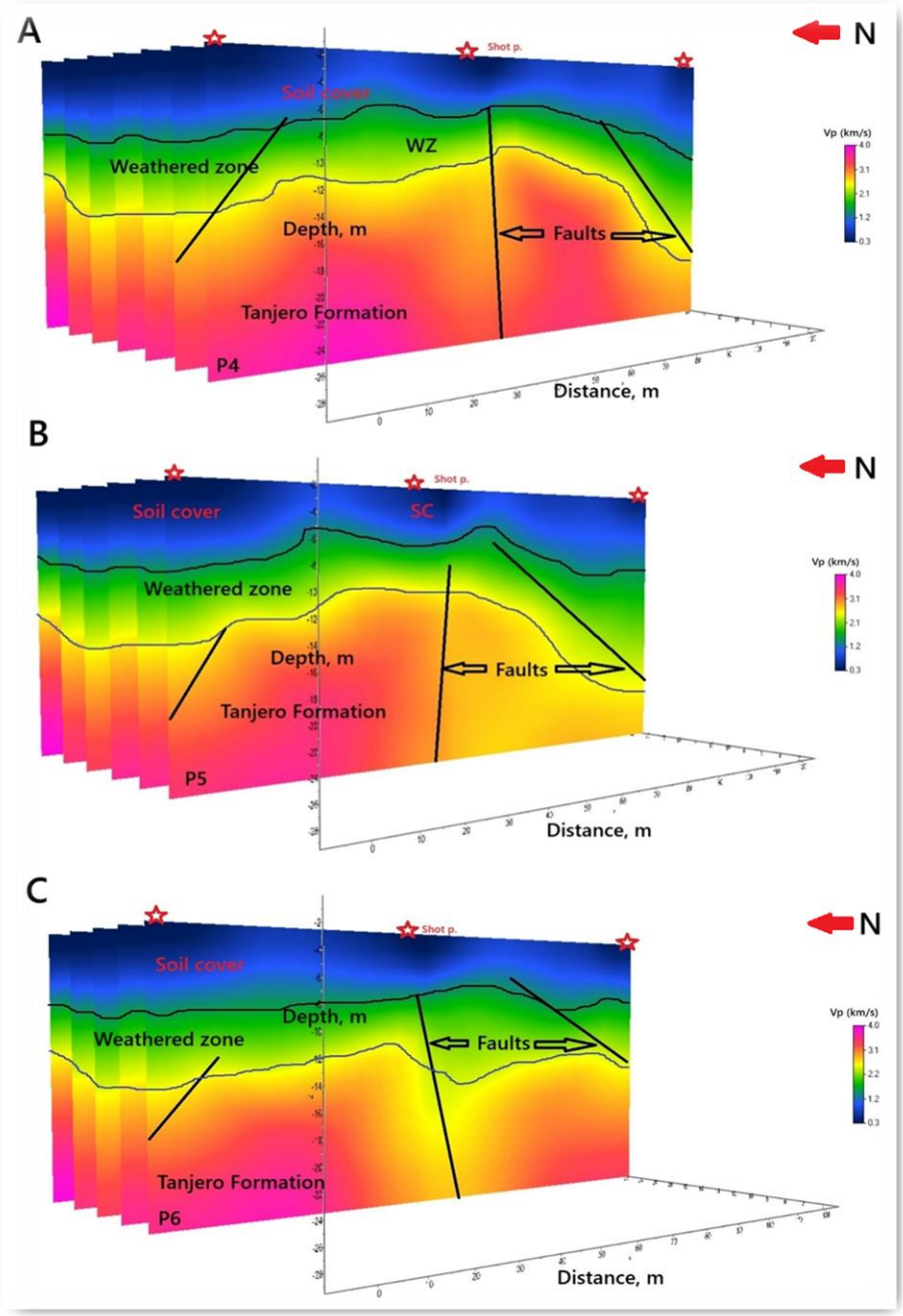


Fig. 15. 3D refraction blocks, A. Profile four. B. Profile five. C. Profile six

The 7thprofile displayed even three layers case, the 1st layer represented by top soil, with thickness of 0-7m, Vp 311.5m/s, Vs 124.5m/s, the 2nd layer of weathered zone with thickness of 7-12m, Vp 23337.3m/s, Vs 949m/s. The 3rd layer which represented by Tanjero Formation having a thickness of 12-30m, Vp 3691m/s, Vs 1023m/s. Faults were also identified in the same location as in the previous profiles. Profile 8this alsorevealed three layers case, the 1st layer is the top soil consisting some rock fragments with thickness of 0-6m, Vp 460m/s and Vs 232.The thickness of the 2nd layer represented by the weathered zone is 6-10m, Vp 2203.5m/s, and Vs 866m/s,whereas the 3rdlayer which represented by Tanjero Formation having thickness ranged between 10-30m, Vp 3114.4m/s and Vs 1391m/s. Faults

are also identified in this profile as in the previous profiles in term of distance and depth. The 9th profile shows even three layers, the 1st layer represented as top soil with thickness about 0-7m, Vp 288.5m/s and Vs 148m/s also, the 2nd layer of weathered zone with thickness of 7-10m, Vp 1982m/s and Vs 455.3m/s. The Tanjero Formation that consists of sandstone and marlstone as the 3rd layer having thickness about 10-30m, Vp 3039.5m/s, Vs 1239m/s. Faults are also traced as in the previous profiles in term of distance and depth, as shown in Fig. 16.

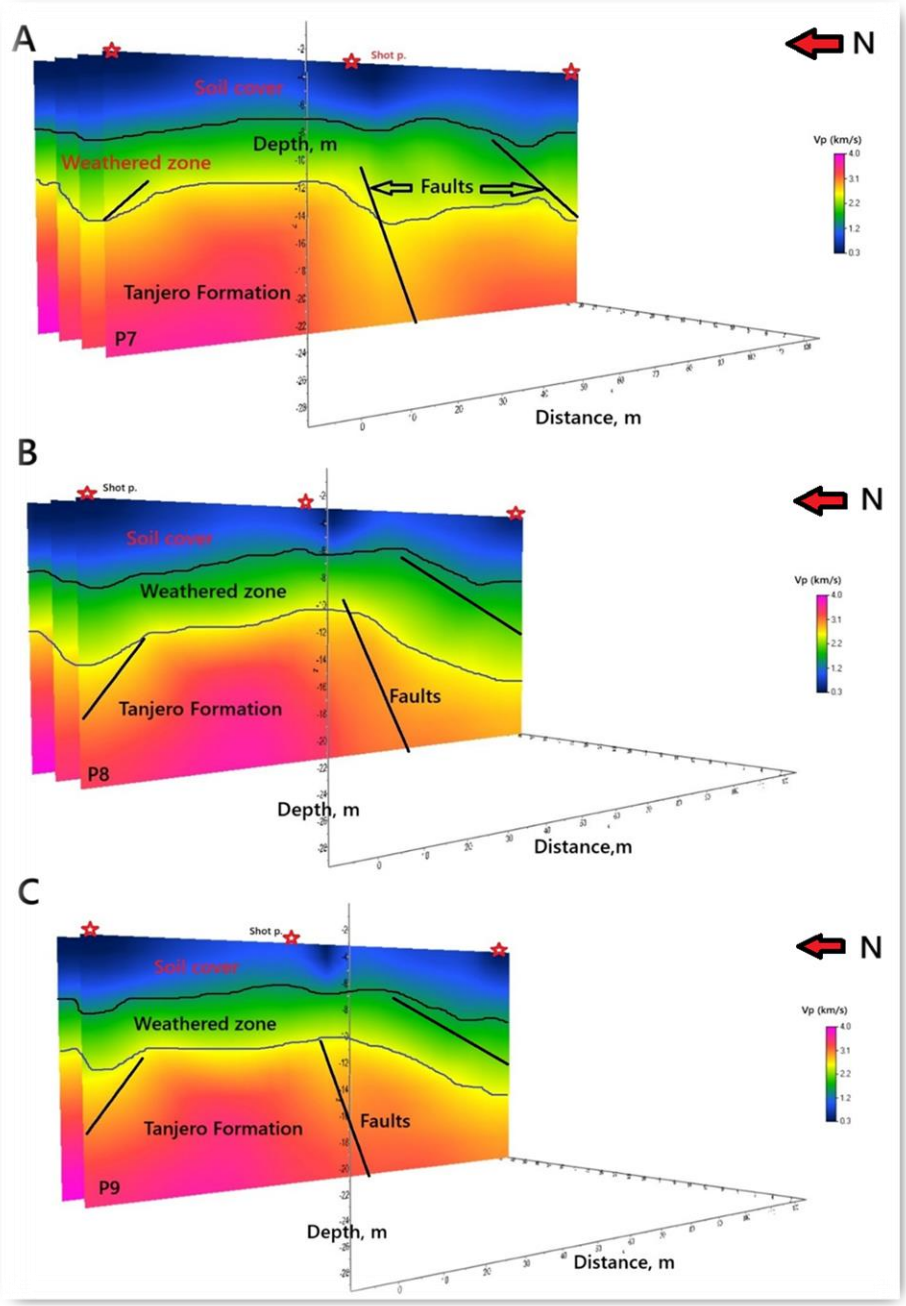


Fig. 16. 3D refraction blocks, A. Profile seven. B. Profile eight. C. Profile nine

The last profile as 10th, revealed also three layer case, the 1st layer of top soil with thickness about 0-6m, Vp 293m/s, Vs 155.5m/s. The 2nd layer of weathered zone has a thickness about 6-13m, Vp 1920.3m/s and Vs 1350m/s,whereas the thickness of 3rd layer which belongs to the Tanjero Formation is about 13-30m, Vp 3016m/s and Vs 1582m/s. Faults were identified in the same distance and depth that displayed in the previous profiles, as shown in Fig. 17.

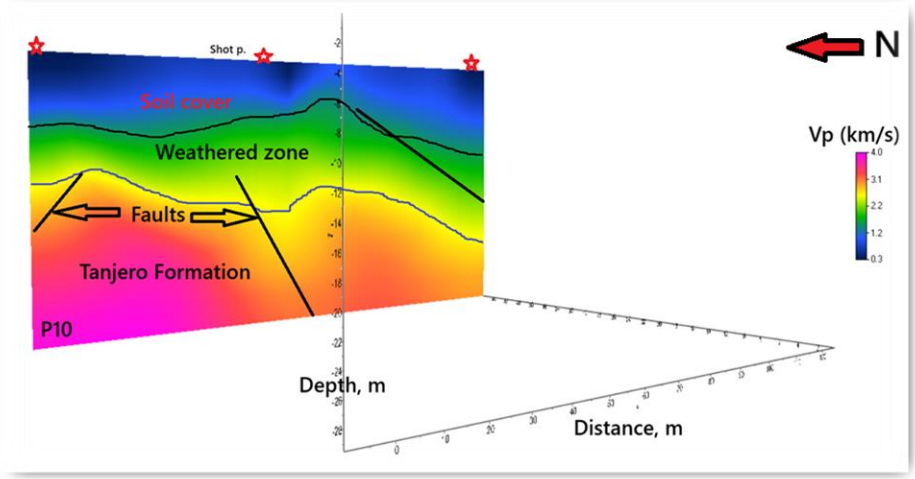


Fig. 17. 3D refraction blocks, profile 10

However, a map is created after connecting togetherthe results of all 10thprofiles which is represented bythe lithology, velocity distributions at different levels and depth, as shown in Fig. 18

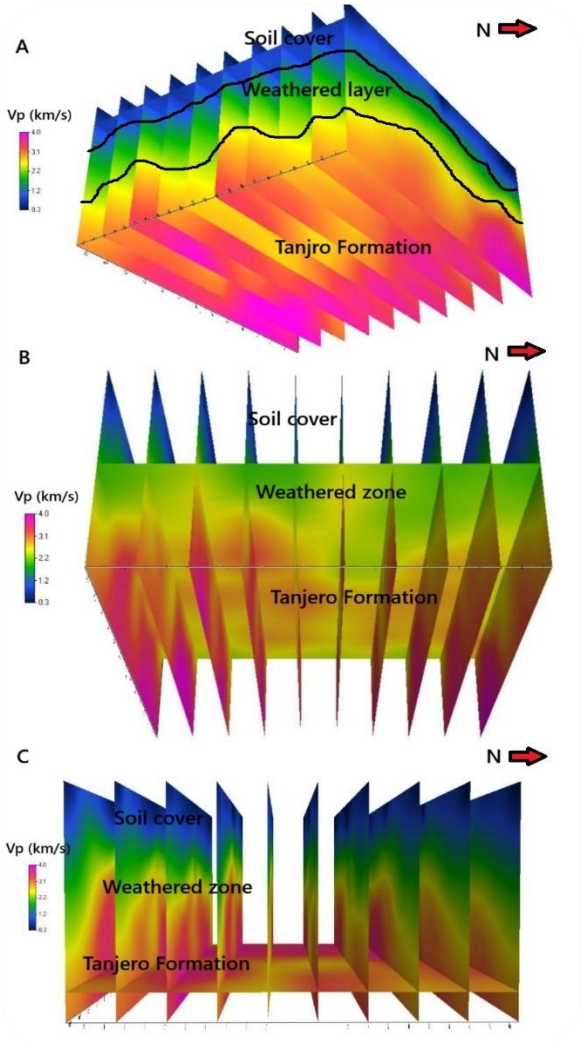


Fig. 18. 3D refraction blocks with different views A. Bottom view when interconnecting map is in the soil cover; B. When the map is in the weathered zone; C. Side view when the map is in the Tanjero Formation

7. Elastic Moduli, Petrophysical and Geotechnical Parameters

The important parameters representing by Elastic moduli, petrophysical and geotechnical one for the studied area were calculated and evaluated, as shown in Table 2.

Table. 2. Results of Elastic moduli, Petrophysical and Geotechnical parameters of the studied area

P.	layers	Vp(m/s)	Vs(m/s)	ρ(gm/cc)	σ'	μ (dyn/cm^2)	E (dyn/cm^2)	K (dyn/cm^2)	ϕ	e	Ci	Si	Mi	qult (kg/m^2)
p1	1	536	140.5	1.492	0.463	2.94E+04	2.54E+10	4.06E+05	0.460	0.853	3.159	0.863	-0.852	2.096
	2	2750	905.3	2.245	0.439	1.84E+06	4.17E+13	1.56E+07	0.174	0.211	3.277	0.783	-0.757	20.323
	3	4748	1904.6	2.573	0.404	9.33E+06	6.31E+14	5.10E+07	0.079	0.085	3.475	0.678	-0.616	49.011
p2	1	601.5	158	1.535	0.463	3.83E+04	4.16E+10	5.27E+05	0.440	0.786	3.160	0.862	-0.852	2.426
	2	2395.6	1340.33	2.169	0.272	3.90E+06	6.71E+13	9.52E+06	0.198	0.247	4.674	0.374	-0.089	29.069
	3	3477	2400	2.380	0.045	1.37E+07	4.97E+14	1.85E+07	0.133	0.153	23.227	0.047	0.820	57.131
p3	1	411.66	173	1.396	0.393	4.18E+04	2.12E+10	2.05E+05	0.506	1.026	3.546	0.647	-0.571	2.416
	2	2507.25	827.5	2.194	0.439	1.50E+06	2.83E+13	1.27E+07	0.190	0.235	3.279	0.782	-0.756	18.152
	3	3605.33	1666.66	2.402	0.364	6.67E+06	2.60E+14	2.62E+07	0.127	0.145	3.746	0.573	-0.456	40.035
p4	1	381.5	152.5	1.370	0.405	3.19E+04	1.39E+10	1.76E+05	0.520	1.082	3.470	0.680	-0.620	2.089
	2	2590	1260.6	2.211	0.345	3.51E+06	7.07E+13	1.22E+07	0.185	0.226	3.900	0.526	-0.379	27.878
	3	3115.5	1820.3	2.316	0.241	7.67E+06	2.23E+14	1.67E+07	0.152	0.180	5.152	0.317	0.037	42.159
p5	1	305	154	1.295	0.329	3.07E+04	8.57E+09	9.75E+04	0.559	1.267	4.040	0.490	-0.316	1.995
	2	2207	1140.6	2.125	0.318	2.76E+06	4.04E+13	8.28E+06	0.213	0.270	4.147	0.466	-0.271	24.235
	3	3849.5	1475.5	2.442	0.414	5.32E+06	2.36E+14	3.22E+07	0.115	0.130	3.416	0.706	-0.656	36.029
p6	1	303	150	1.293	0.338	2.91E+04	8.02E+09	9.69E+04	0.560	1.273	3.961	0.510	-0.351	1.940
	2	2198.33	882.33	2.123	0.404	1.65E+06	2.40E+13	9.02E+06	0.213	0.271	3.475	0.678	-0.616	18.729
	3	3151.5	1155	2.323	0.422	3.10E+06	9.23E+13	2.07E+07	0.150	0.177	3.367	0.731	-0.690	26.827
p7	1	311.5	124.5	1.302	0.405	2.02E+04	5.88E+09	1.11E+05	0.555	1.248	3.469	0.681	-0.620	1.621
	2	2337.33	949	2.155	0.401	1.94E+06	3.18E+13	1.03E+07	0.203	0.254	3.492	0.670	-0.605	20.455
	3	3691	1023	2.416	0.458	2.53E+06	1.03E+14	3.10E+07	0.123	0.140	3.182	0.846	-0.834	24.719
p8	1	460	232.5	1.436	0.328	7.76E+04	4.93E+10	2.46E+05	0.487	0.949	4.045	0.489	-0.314	3.338
	2	2203.5	866	2.124	0.409	1.59E+06	2.32E+13	9.12E+06	0.213	0.270	3.447	0.691	-0.635	18.393
	3	3114.5	1391	2.316	0.375	4.48E+06	1.30E+14	1.91E+07	0.152	0.180	3.664	0.601	-0.502	32.213
p9	1	288.5	148	1.278	0.321	2.80E+04	6.99E+09	8.53E+04	0.569	1.318	4.111	0.474	-0.286	1.891
	2	1982	455.3	2.068	0.472	4.29E+05	5.05E+12	7.80E+06	0.231	0.301	3.118	0.894	-0.889	9.417
	3	3039.5	1239	2.302	0.400	3.53E+06	9.79E+13	1.86E+07	0.157	0.186	3.498	0.668	-0.601	28.519
p10	1	293	155.5	1.283	0.304	3.10E+04	7.99E+09	8.68E+04	0.566	1.304	4.290	0.437	-0.216	1.994
	2	1920.33	1350	2.052	0.011	3.74E+06	4.14E+13	4.76E+06	0.237	0.311	88.428	0.012	0.954	27.704
	3	3016	1582	2.297	0.310	5.75E+06	1.57E+14	1.66E+07	0.158	0.188	4.224	0.450	-0.241	36.343

The Elastic moduli parameters consist of Poisson's ratio (σ), Rigidity modulus (μ), Young modulus (E) and Bulk modulus (K). The petrophysical parameters include, porosity (ϕ), void ratio (e) and density (ρ). While the geotechnical parameters were including, concentration index (Ci), stress index (Si), material index (Mi) and ultimate bearing capacity (qult). The results appeared that the Poisson's ratio ranged between 0.2-0.4, Rigidity 2E+04-9E+06dyn/cm^2, young modulus 1E+10-6E+14dyn/cm^2, Bulk modulus 1E+07-9E+06dyn/cm^2, porosity 0.1-0.5, void ratio 0.1-1.2, Ci 1.2-4, Si 0.04-0.8, Mi -0.2 to -0.8 and qult 2-49 kg/m^2. In comparison to the previous studies in this area (Baban et al., 2022), the Vp and Vs shown theirvalues as greater than the current one because Baban et al. (2022) conducted their study on the Kometan Formation in which it consists hard limeston, high density and competent material deposits.

In the profile one, the higher density value appears in the third layer as 2.5 gm/cc, on the other hand, the highest Poisson's ratio was appeared in the first layer as 0.46 which it is characterized as incompetent to slightly competent sediment materials. The high Rigidity, Young and Bulk modulus for the third layer indicate their high elasticity. It can be seen that the first layer has high porosity 0.46 and void ratio 0.85, these indicate that the top soil is loose and incompetent sediment materials. by inspecting the values of Ci, Si and Mi for the same layer, it shouldindicate very weak layers to fairly or moderate competent, while the Ultimate bearing capacity of the third layer is high 49.01kg/m^2 in comparison to the first and second layer, therefore it is characterized as resist to high loads. In profile two, the density of the third layer is high 2.3 gm/cc, Poisson's ratio is very low 0.045 which indicates a competent layer, even the high elastic modulus parameters for this layer may indicate high elasticity, , whilistthe porosity and void ratio of the first layer are high, so it contains loose sediments and incompetent materials. The Parameter values of Ci, Si and Mi,on the other hans, may indicate that the third layer is moderate to high competent,this is consistent with the values of the ultimate bearing capacity which is high as 57.1kg/m^2,then it is considered to be resists to a high load.In profile three, density of the third layer is also high 2.4gm/cc while Poisson's ratio is 0.36, indicates that it is fairly to moderate competentwith high elastic layer. High values of both porosity and void ratio for the first layer as 0.5 and 1.02 respectively indicate that the first layer is soft and incompetent. From inspecting the geotechnical parameters of Ci, Si and Mi, it indicates soft and incompetent layers in turnthe maximum ultimate bearing capacity for the third layer as 40.03kg/m^2, indicate their resist to a high load. In profile four the density value of the third layer is high as 2.3gm/cc even Poisson's ratio as 2.4 indicates that it is competent material and has high elasticity according to the elastic moduli. The first layer, on the other hand, revealed high values for the porosity and void ratio as 0.5 and 1.08,which indicate incompetent material. From geotechnical parameters of Ci, Si and Mi for the third layer indicates their sediments as moderate to compact material added to its maximum ultimate bearing capacity value as 42.1kg/m^2. In profile five, the density of the third layer is high 2.4gm/cc in comparison to the first and the second layersin turn with low porosity and void ratio 0.11 and 0.13 respectively,so, it is considered to be competent sediment materials. According to the values of Ci, Si and Mi, with high ultimate bearing capacity 36.02gm/cc, it is appearedas soft to fairly compactmaterial.

In profile six, the third layer has high density as 2.3gm/cc and low porosity with void ratio, this characteristic indicate it is competent with high elasticity, in turnit shows weak to slightly competent according to the values of Ci 3.3, Si 0.73 and Mi -0.69 with high ultimate bearing capacity 26.8kg/m^2. In profile seven, the first top soil layer has low density as 1.3gm/cc and high for the porosity 0.55 andvoid ratio 1.2 that indicate incompetent material. In this profile most layers are in zone of incompetent to fairy competent according to the values of Ci 3.1-3.4, Si 0.6-0.8, and Mi -0.6 to -0.8,however, the ultimate bearing capacity value of the third layer is high as 24.7kg/m^2. According to the values of density as high, porosity and void ratio, low, added to the values of Ci 3.6-4, Si 0.48-0.6 and Mi -0.3 to -0.6 and the ultimate bearing capacity 32.2kg/m^2, for the profile 8, the third layer consider

to be competent and elastic in comparison to the first and second layers. In profile nine, the maximum density is in third layer 2.3gm/cc with low porosity value as 0.15 and void ratio as 0.18 which indicate competent material. According to the Poisson's ratio 0.3-0.4, Ci 3.4-4, Si 0.4-0.8 and Mi -0.2 to -0.8 and maximum ultimate bearing capacity for the third layer, most of the layers consider to be incompetent to fairly competent materials. In the last profile, 10, according to the values of density, porosity, elastic moduli, Poisson's ratio, Ci 4.2, Si 0.45 and Mi -0.24 with high ultimate bearing capacity as 36.3kg/m^2 , the third layer is consider to be fairly competent material in comparison to the other adjacent layers.

8. Conclusions

According to the results given above, some conclusions can be given as the following:three different layers as top soil with soft and rock fragments, weathered zone and Tanjero Formation which consists of sandstone and claystone or marlstone.

The maximum depth was obtained with profile length as 115m was about 30m.The depth of these layers were calculated and given as, the first top soil layer as 0-6m, the second layer of weathered zone as 6-12m and the third layer which represented by the Tanjero Formation is 12-30m,respectively.In turn, the obtained velocity of Vp for the first layer is 300-600m/s, the second layer is 1800-2500m/s and for third layer is 3100-400m/s. The obtained velocity of Vs, on the other hand, for the first layer is 140-170m/s, the second layer 800-1300m/s and for the third layer is 1800-2400m/s. Finally and according to the international classifications to the geotechnical parameters, the evaluation of the given parameters as Elastic moduli, petrophysical and geotechnical ones, revealed that the first layer is weak, soft (i.e. incompetent), the second layer is mainly soft to fairly competent while the third layer is considered to be fairly to moderate competent and compact. However, three faults located at the beginning of the profiles, at distance of 60m and at 100m, where extending to the depth were determined.

9. Recommendations

It is recommended that this research cauld be carried out for many projects including, Dams, Roads, Towers and any other large projects. The lithology of the Tanjero Formation appeared as it is not very competitive, so, the projects requires a good foundation, if the implementation is approved.

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