A Study of the weathering layer using uphole method Concession 11, Sirte basin / Libya.

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الملخص:

في هذه الورقة، تم تنفيذ مسح سيزمى انكساري بئري Uphole method يهدف الاستخدام هذه طريقة لدراسة ومعرفة طبقة التجوية في منطقة الدراسة وكذلك معرفة سرعتها السيزميه بغرض استخدام هذه المعلومات في التصحيحات الاستاتيكيه في مرحله المعالجة اللاحقة لمعلومات سيزميه ثلاثية الابعاد 3D seismic survey. طبقات التجوية عادتاً تتميز بان سرعة الموجات السيزميه فيها منخفضه ومتغيره جانبياً بشكل حاد. وطبقة التجوية يمكن ان يُتعرف عليها باستخدام هذه الطريقة من خلال التباين بينها وبين الطبقات الأكثر تماسكاً التي تتموضع تحتها والتي تُظهرها سرود الأبار. تم حفر 138 بئراً سطحيه Upholes في منطقة الدراسة وتم اجراء سرود او تسجيلات لهذه الأبار. الأبار المحفورة تم سردها او تسجيلها من أسفل الى اعلى. السرود الناتجة من كل بئر تم استعمالها لتمييز الحدود الفاصلة بين طبقة التجوية والطبقات التي تحتها. تفسير البيانات يُظهر بوضوح أن هناك أربع طبقات تم اختراقُها في اغلب الأبار المحفورة. الطبقتين العلويتين يمكن اعتبارها طبقات تجويه. سمك طبقة التجوية يتراوح ما بين 20 متر في الجزء الشرقي من منطقة الدراسة الى أكثر من 100 متر في الجزء الغربي والجزء الجنوبي الغربي. سرعة الموجات السيزميه في الطبقات تحت طبقة التجوية تتراوح ما بين 1600 متر/ثانيه الى 2500 متر/ثانيه. تم تقدير سرعه استبدال

Replacement velocity باستخدام متوسط الحسابي للسرعة في الطبقة تحت طبقة التجوية لتكون 2000 متر/ثانيه.

Abstract

In this paper, an Uphole refraction survey was carried out aimed at using the uphole method to investigate the velocity and thickness of the weathering and sub weathering layer, in essence, obtain values for static correction to be used in the processing of 3D seismic reflection data. Weathering layers are often characterized by low seismic velocities. Base of weathering can be described as the boundary between the weathered layer and consolidated layer. Total 138 Uphole locations were drilled and logged. The holes were logged from bottom of the hole to the top. Drilling logs from each Uphole point were used in conjunction with the theoretical interpretations as a physical data set to aid in making inferences for boundary distinction. Data interpretation shows clearly that there are four layers were penetrated by the Upholes. Two upper layers can be considered as weathering layers. The thickness of the weathering layer is clearly varied and ranging from 20m in the east part to more than 100 m in the west and southwest. Velocity of subweathering layer ranges between 1600 m/s to 2500 m/s. Replacement velocity was estimated at 2000 m/s. calculated from the arithmetic average of the velocities obtained from the sub weathering layer.

KEY WORDS: *Uphole survey* weathered layer* Seismic Refraction* static correction* Replacement velocity**

INTRODUCTION

Uphole survey provides the most direct measure of the thickness and vertical velocity of the weathered layer. The weathered layer or low-velocity layer (LVL) is the shallow subsurface layer composed of unconsolidated materials such as soil, sand and gravel. It is heterogeneous in composition and is characterized by low seismic velocity which account for the delay experienced in travel time of the seismic wave. The weathered layer is also characterized by high porosity, lack of cementation, low pressure and low bulk modulus. The base of the weathered layer can be referred to as the interface between the weathered layer and the consolidated layer. Measuring thickness and vertical velocity of the weathered layer by drilling a hole and taking a shot on the surface, and recording the refracted wave response via a geophone/hydrophone suspended at certain intervals in a vertical column bore through the weathered layer (Fig1). The arrival times and charges depths are plotted. The slope of the first line yields the velocity of the weathered layer; the slope of the second line yields the velocity of the sub-weathered layer. The point of the velocity break yields the thickness of the layer. . the uphole survey aimed at using the uphole method to investigate the thickness of the weathering layer as well as the velocity of seismic waves through it, in essence, obtain values for static correction to be used in the processing of reflection data static correction (statics) a correction applied to seismic data to compensate the effect of irregular topography, differences in the elevation of shots and geophones relative to a datum, low-velocity surface layers (weathering correction), and the horizontal geometry of shots and receivers (geophones or hydrophones).

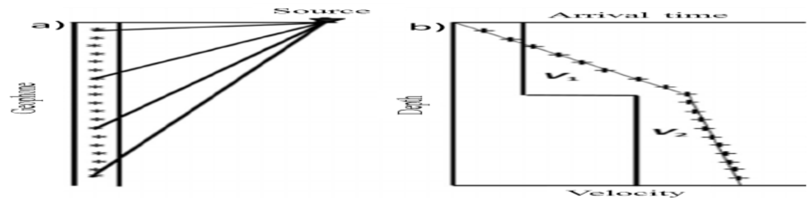


Fig 1) An Uphole survey (a) Field layout. (b) Corrected first break times (+) and derived velocity (solid line).

A static correction provides some form of direct-current shift (e.g. in seismic-reflection surveys), usually a time element added to or subtracted from the travel times. Datum statics corrections require that the weathered layer be removed and the times adjusted from the base of the weathered layer up to, or down to the reference datum. The velocity used for this correction is normally called the replacement velocity, or sometimes the datum velocity, elevation velocity or sub-weathering velocity if the reference datum is below the base of the weathered layer. The replacement velocity is normally computed from the velocity profile at this depth, that is, the velocity within the sub-weathered layer. If datum is above the base of the weathered layer, material with a velocity close to that at the base of the weathered layer is used to infill the layer. The replacement velocity may be constant for a line or, may change slowly along the line. Where major lateral changes in geology, and hence velocity occurs at or just below the base of the weathered layer, the replacement velocity profile generally reflects these changes.

Variations in the physical properties of upper layer can significantly degrade the quality of Earth's seismic data if not addressed. Static correction usually takes place early in the seismic information processing stage, which is one of the most important correction stages, which must be carried out carefully in order to ensure good results.

STUDY OBJECTIVES

The study aims to interpret the information obtained from the Uphole program and can be summarized as follows:

- Determine the depth of the weathering layer in the study area.
- Finding the replacement velocity that will be used in static correction.

LOCATION AND TOPOGRAPHY

BGP International (LIBYA) Inc. contracted with Veba Oil Operations (V.O.O.) to undertake 3D land seismic survey in concession 11. An uphole seismic refraction survey was carried out in conjunction with the seismic survey. The Concession 11 is located in the North-West of Sirte basin in LIBYA. It is almost 350Km west of Hun town, approximately 700 km SE of Tripoli. The nearest town Zillah is about 40Km to base camp (Fig 2). The terrain is a harsh desert area, sand dunes, and escarpments. The operating area is about 70 percent a desert interspersed with some arid highlands and 30 percent flat sandy areas. The terrain was very rough in the escarpment area. The elevation level of the area ranges from 66 m in the west to 315 m above sea level in the southwest (Fig 4). Some oil wells, pipelines, power lines, and other buildings were distributed in the area. There are four different morphological features, flat rocky zones, rocky outcrop zones, hilly zones, and mountainous zones.

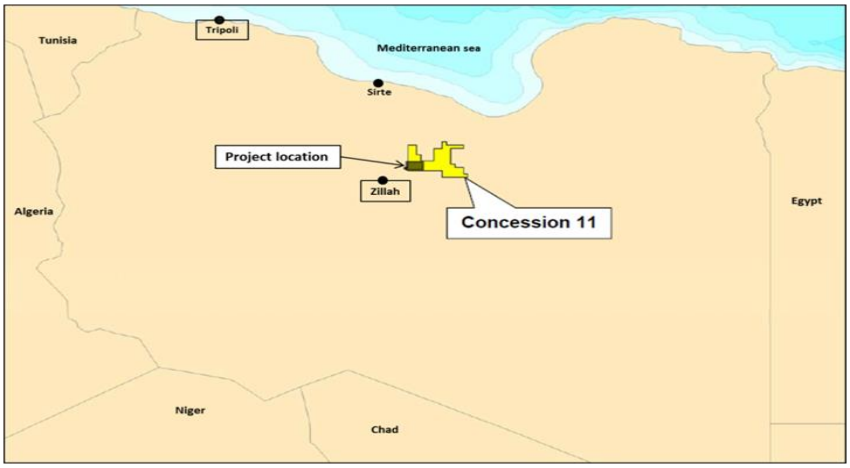
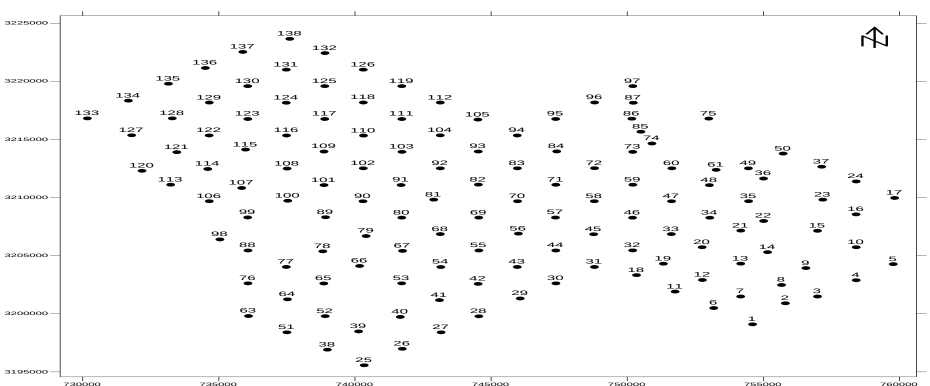


Fig 2) 3D seismic survey location (H.O.O, 2004). An uphole seismic refraction survey was carried out in conjunction with the seismic survey. The total project area is estimated at 483km².

LOGGING & PROCESSING

Total 138 Uphole locations were drilled and logged, the Uphole locations are shown in (Fig 3). Logged depth varies from about 80m to more than 200m. Upholes were recorded on a GEOMETRICS R24 24-channel refraction camera, via down hole geophone. For source of energy, hammer-plate combination was used, placed 2.5 m from the hole. The holes were logged from bottom of the hole to the top. The geophone was lowered to bottom of hole then coupled to the hole wall by releasing a spring-arm mechanism. Recordings were taken at 2.5 meter /intervals up the hole; an additional recording was made at zero depth to check instrument timing. The bottom of the hole will be logged at 2.5 m intervals to ensure the final velocity is accurately determined, 11 points were recorded, in the shallow depth (2.5 m to 25 m), 10 points were recorded with depth interval 2.5 m. The depth between middle parts was recorded with depth interval 5 m.

Uphole data was recorded and downloaded to computer and processed, using proprietary BGP KLSEIS software. From first-arrival times picked manually of the computer display the software produced a time/depth plot. Best-fit lines were chosen by the processing geophysicist via an interactive display. The final results obtained from the program are shown in table(1)



(Fig 3) Upholes locations map, some of the Upholes were re-drilled, canceled or shifted

Table 1 shows Elevation of Upholes location (Z), Velocities of drilled layers (V) and thickness of penetrated layers (h).

Easting	Northing	Z (m)	Name	V0	V1	V2	V3	h0	h1	h2
754602	3199095	128	1	487	1298	1817	2506	3	13	19
755810	3200908	121	2	315	939	1555	2215	3	11	32
756988	3201487	126	3	458	1438	1852	2740	8	26	24
758408	3202888	104	4	463	1032	2079	2851	2	13	34
759769	3204274	134	5	853	1614	2012	2533	4	18	54
753177	3200496	110	6	308	1140	1998	2797	3	15	29
754166	3201486	103	7	293	1560	2014	2425	3	27	33
755666	3202479	176	8	734	1894	2221		4	78	
756562	3203934	145	9	346	786	1652	2545	4	16	30
758408	3205729	123	10	660	1531	2154	2839	3	29	45
751758	3201910	112	11	436	1355	1969	2260	3	8	45
752761	3202909	119	12	936	1784	2252		6	46	
754167	3204313	118	13	580	1385	2149	2698	5	22	21
755154	3205304	102	14	560	1441	2684		5	23	
756987	3207139	108	15	397	1627	2259		4	26	
758404	3208556	119	16	860	2020	2779		14	54	
759820	3209968	118	17	471	1866	2441		3	50	
750341	3203326	141	18	602	1470	1903	2207	5	9	68
751327	3204308	134	19	268	1015	1907	2203	3	8	26
752750	3205728	114	20	367	898	1799	2487	3	12	18
754169	3207157	91	21	423	2353	3332		5	74	
755009	3207987	91	22	384	666	2467		2	8	
757181	3209820	100	23	369	1528	2423		4	26	
758408	3211389	101	24	249	932	2231		3	12	
740339	3195573	232	25	982	1850	2267		7	77	
741737	3196991	233	26	1424	1903	2350		40	93	
743163	3198408	187	27	527	1774	2208		3	68	
744549	3199787	183	28	453	1466	2221		4	38	
746070	3201318	175	29	431	1896	2457		4	74	
747381	3202621	157	30	423	1230	1832	2738	4	17	41
748794	3204030	144	31	502	1913	2202		6	69	
750200	3205457	138	32	452	1559	1948	2549	4	24	72
751618	3206857	113	33	243	1336	2662		2	26	

Easting	Northing	Z (m)	Name	V0	V1	V2	V3	h0	h1	h2
753032	3208264	103	34	359	1559	2584		3	16	
754456	3209689	89	35	302	650	2518		3	8	
755006	3211637	89	36	276	619	1667	2472	3	17	17
757141	3212653	78	37	374	1051	2539		3	11	
738988	3196913	257	38	296	952	1798	2234	3	39	119
740133	3198485	263	39	1209	2637	1500	2847	11	38	17
741665	3199732	227	40	472	1689	3242	2054	3	13	14
743103	3201175	205	41	476	1512	1952	2213	4	20	93
744525	3202576	201	42	515	1447	1931	2435	5	27	83
745962	3204030	174	43	378	1308	2049	2512	4	28	48
747376	3205445	153	44	369	1616	1904	2590	3	37	59
748767	3206846	151	45	467	1378	1925	2210	4	21	28
750195	3208266	122	46	295	976	2008	2609	3	13	24
751625	3209682	106	47	450	1164	2011	2514	4	10	14
753016	3211069	107	48	611	1493	2475		5	19	
754450	3212515	74	49	189	1104	2474		3	11	
755725	3213786	66	50	426	2068	2539		3	25	
737501	3198408	269	51	453	1094	1862	2226	6	33	116
738907	3199796	270	52	1329	2805	1294	1834	15	45	24
741716	3202621	243	53	803	1414	1917	2259	9	72	60
743152	3204023	213	54	851	1723	2217		11	71	
744550	3205447	176	55	391	1329	1783	2246	3	22	54
746001	3206895	177	56	335	1449	1980	2239	4	8	59
747363	3208281	148	57	544	1736	2321		5	27	
748789	3209687	123	58	399	1117	1974	2691	5	13	28
750207	3211103	124	59	383	1055	2091	2419	4	13	27
751638	3212518	107	60	248	1204	2497		3	22	
753264	3212383	83	61	338	1353	2211		3	15	
754423	3215312	70	62	325	923	2039	2645	4	10	35
736089	3199808	316	63	1382	1824	2592		105	90	
737520	3201248	290	64	1567	1810	2319		66	109	
738855	3202610	270	65	509	1607	2623		2	50	
740169	3204116	253	66	1131	2971	1794	2457	13	52	107
741748	3205414	208	67	294	1073	1815	2213	4	27	68
743134	3206858	182	68	285	1142	1786	2225	3	14	58
744547	3208274	166	69	453	813	1855	2306	3	7	54

745970	3209685	154	70	319	1109	1862	2314	3	9	38
747376	3211101	137	71	508	1111	1790	2418	2	14	33
748798	3212528	118	72	419	1352	1968	2460	4	14	31
750203	3213929	81	73	434	2515			4		
750906	3214651	94	74	320	650	1760	2286	3	24	38
752994	3216793	118	75	893	1880	2233		4	64	
736070	3202620	297	76	2138	1141	1827	2221	29	35	135
737477	3204031	277	77	1507	2703	1842	2219	52	62	68
738820	3205375	258	78	462	1827	2259		4	125	
740410	3206689	262	79	1770	2256			140		
741719	3208273	213	80	362	1518	1788	2244	4	39	65
742893	3209821	228	81	1550	2240			110		
744531	3211112	170	82	505	1482	1963	2236	4	15	49
745964	3212518	135	83	391	1374	1930	2359	3	18	52
747409	3213972	119	84	565	1487	1976	2214	3	16	63
750501	3215663	105	85	307	579	1802	2364	3	24	41
750168	3216784	84	86	308	525	1789	2392	3	15	15

Easting	Northing	Z (m)	Name	V0	V1	V2	V3	h0	h1	h2
750223	3218155	71	87	402	665	2069	2436	4	15	15
736071	3205447	284	88	2139	1461	1771	2226	44	29	106
738919	3208308	252	89	1329	3615	1782	2296	12	38	93
740295	3209684	218	90	431	986	1800	2264	4	33	78
741694	3211077	203	91	267	1281	1685	2255	3	29	56
743134	3212516	156	92	658	1678	2530		7	62	
744527	3213962	129	93	826	1909	2218		6	64	
745961	3215345	113	94	400	1461	1989	2651	4	18	61
747372	3216761	93	95	430	1066	2066	2856	3	14	33
748802	3218181	80	96	392	1992	2485		4	16	
750204	3219587	69	97	461	982	2032	2569	4	12	33
735040	3206401	292	98	814	1514	1772	2214	4	72	82
736060	3208291	268	99	1214	3990	1993	2246	30	38	88
737531	3209724	272	100	925	1841	2242		23	145	
738863	3211074	255	101	828	2742	1846	2217	6	26	118
740305	3212519	192	102	455	991	1710	2290	3	22	55
741726	3213933	165	103	379	831	1654	2240	3	7	33
743131	3215353	127	104	712	1928	2209		7	55	
744514	3216708	118	105	354	1005	2159	2377	4	9	40

734648	3209686	270	106	688	3474	1655	2066	4	40	27
735840	3210824	268	107	700	1237	3167	1899	3	21	33
737508	3212495	255	108	711	2768	1808	2249	3	28	105
738862	3213959	191	109	288	1572	2212		4	69	
740314	3215333	163	110	577	1240	2200		3	33	
741721	3216756	148	111	615	1899	2206		8	38	
743134	3218173	133	112	608	1844	2210		7	30	
733231	3211105	277	113	951	4070	1744	1922	3	43	28
734593	3212458	271	114	920	1496	1855	2217	3	88	65
735981	3214128	202	115	453	728	1878	2264	4	14	87
737487	3215343	169	116	254	1743	2247		3	60	
738890	3216760	161	117	664	1564	2238		3	34	
740308	3218177	157	118	665	1222	2204		5	18	
741718	3219586	139	119	359	1730	2077	2503	4	25	51
732180	3212303	285	120	3547	1528	2051	2250	43	52	86
733459	3213905	214	121	475	1555	1860	2104	3	33	56
734645	3215345	185	122	457	1779	2085	2305	3	46	55
736066	3216759	187	123	719	1071	1972	2337	4	27	60
737477	3218156	149	124	459	1842	2414		5	32	
738891	3219587	137	125	420	1468	2241		3	22	
740305	3221002	127	126	425	1493	2088	2379	4	14	17
731798	3215359	275	127	816	3203	1356	1882	3	34	41
733291	3216815	194	128	306	710	1914	2779	3	12	109
734649	3218172	173	129	452	1739	2024	2359	3	45	70
736062	3219587	157	130	506	901	2084	2600	3	15	61
Easting	**Northing**	**Z (m)**	**Name**	**V0**	**V1**	**V2**	**V3**	**h0**	**h1**	**h2**
737477	3221002	135	131	289	1203	2031	2385	5	20	46
738899	3222429	126	132	725	1573	2328		6	25	
730172	3216814	277	133	729	2532	1455	1844	3	21	71
731679	3218335	207	134	260	1107	1878	2213	3	25	73
733149	3219790	197	135	384	751	1270	1864	3	10	11
734505	3221148	164	136	233	1687	2335		3	47	
735881	3222531	147	137	365	1233	1727	2343	3	21	40
737605	3223655	115	138	506	1471	2396		4	25	

INTERPRETATION

By presenting and analyzing the results obtained, it is clear that the weathering layer or low-velocity layer (LVL) in the study area is consisting of more than one layer. The first layer is an eolian sedimentary layer *(loess created by wind)* that covers the surface of the area. It is a relatively thin layer which ranges from 4 m to about 10 m, although in some locations its thickness was much bigger, reaching more than 100 m. but what is prevailing in the region is otherwise. In general, the surface and near-surface layers are characterized by a sudden variation in their thickness due to the shape of the Earth's surface at the time of sedimentation, as well as the variation in the seismic velocity. The velocity of seismic waves in the first layer is very low, in some places very close to the velocity of seismic waves in the air at the northeastern and east part of the study area, and the velocity begins to increase to the southwest direction. Seismic wave velocity at first layer ranges from 300 m/s to 2000 m/s (Fig 5). As a result, since it is not a thick layer, it hardly shows up in the relationship curve.

The second layer is mostly clay, it’s more homogeneous than the first layer in terms of thickness and velocity of the seismic waves, but it still has a clear variation in the seismic velocity which ranges from 1500 m/s to 3200 m/s (Fig 6), and the rapid lateral change of the seismic velocity is still clearly noticeable. The seismic velocity in the second layer almost has the same behavior as the velocity in the first layer, so that it increases clearly in the southwestern part. The reason may be due to the fact that the southwestern region is a hilly and mountainous area (Fig 4) and they are devoid of sedimentary layers that cause the velocity to slow down.

The first and second layers together can be considered as a weathering layer because the velocity of seismic waves in them is extremely low in several locations and varies greatly along them. The top of the sub-weathering layer or the thickness of weathering layer is shown in (Fig 8). The thickness of the weathering layer is clearly varied, ranging from 20m in the east part to more than 100 m in the west and southwest so it is thicker in the southwestern region, which is an elevated area interspersed forming unconnected mountains.

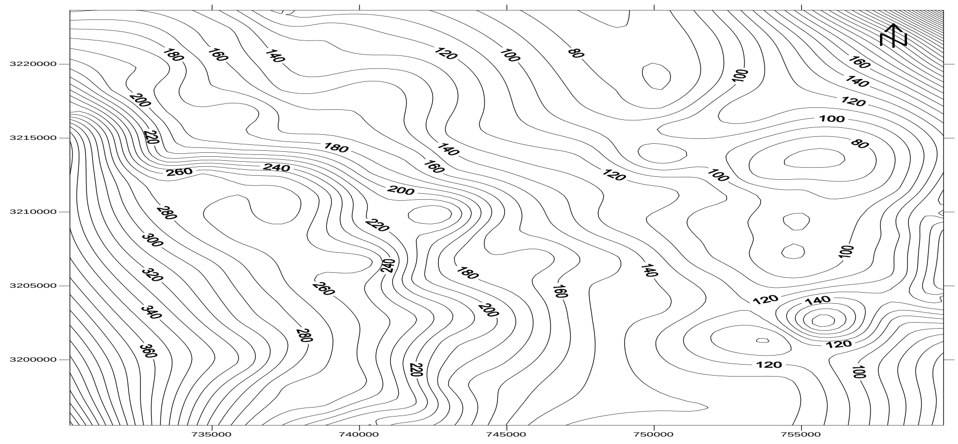
The third layer is mostly mudstone shows more stability in the horizontal distribution of the seismic velocity, which is between 1600 m/s to 2500m/s (Fig 7), and it is relatively thick compared to the layers above it, and it ranges from 20 m to more than 100 m in some locations with an average value of 50 m. This layer can be considered as a sub-weathering layer.

The fourth layer has not been penetrated by the Upholes in all drilling sites. The velocity of the seismic waves ranges in the locations in which it appeared between 2100 m/s to 2800 m/s, and since no layers appeared under it in any of the drilling sites, therefore its thickness cannot be predicted

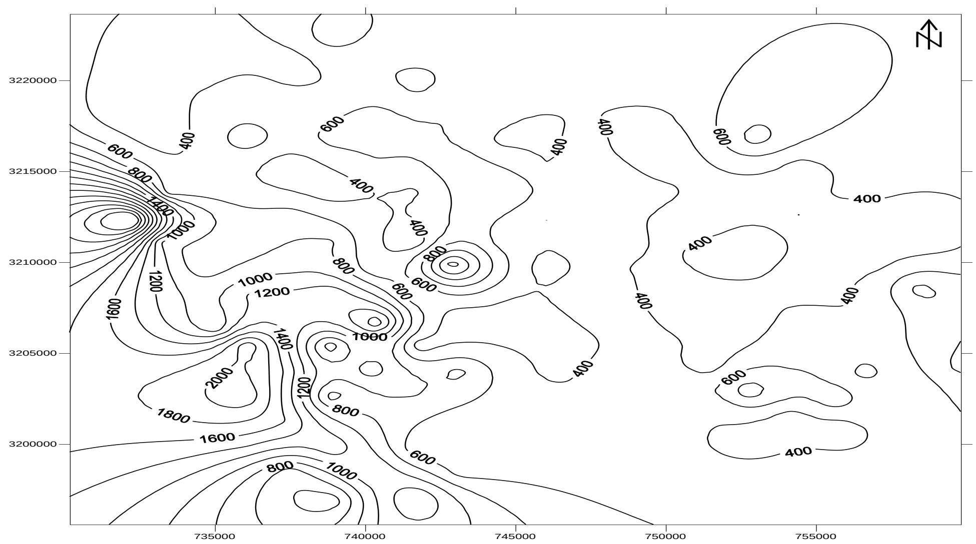
REPLACEMENT VELOCITY

Upholes principally go deep into the sub-weathering layer to detect their velocity. Since the velocity of seismic waves in sub weathering is fairly more stable compared to the weathering layer above it therefore it may sometimes be easy to determine the replacement velocity. However, if the study area is wide so that the lateral change of the seismic velocity is very probable, then more than one replacement velocity can be used to obtain better static correction results. By calculating the average velocity of sub-weathering layer V2, it was found to be approximately 2000 m/s.

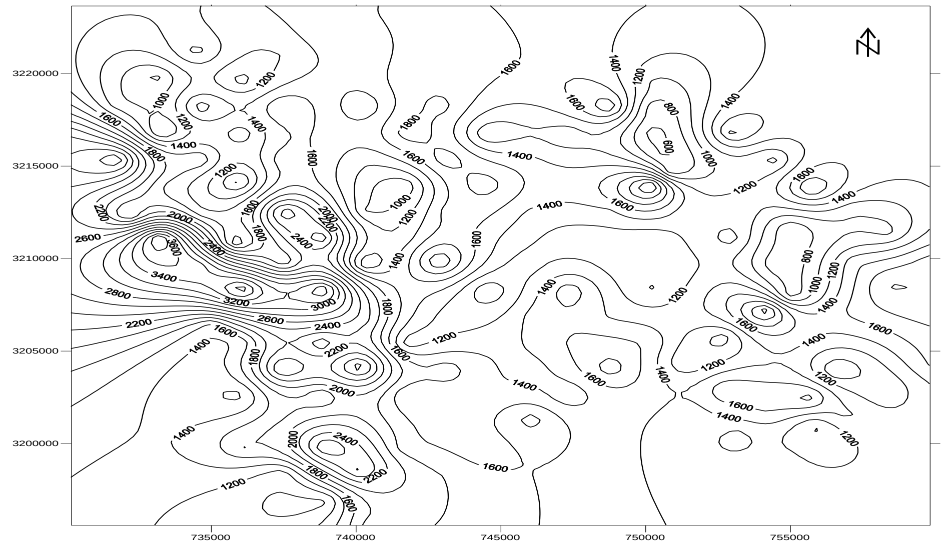
This value can be tested in seismic data processing stage to see its success and change it if required



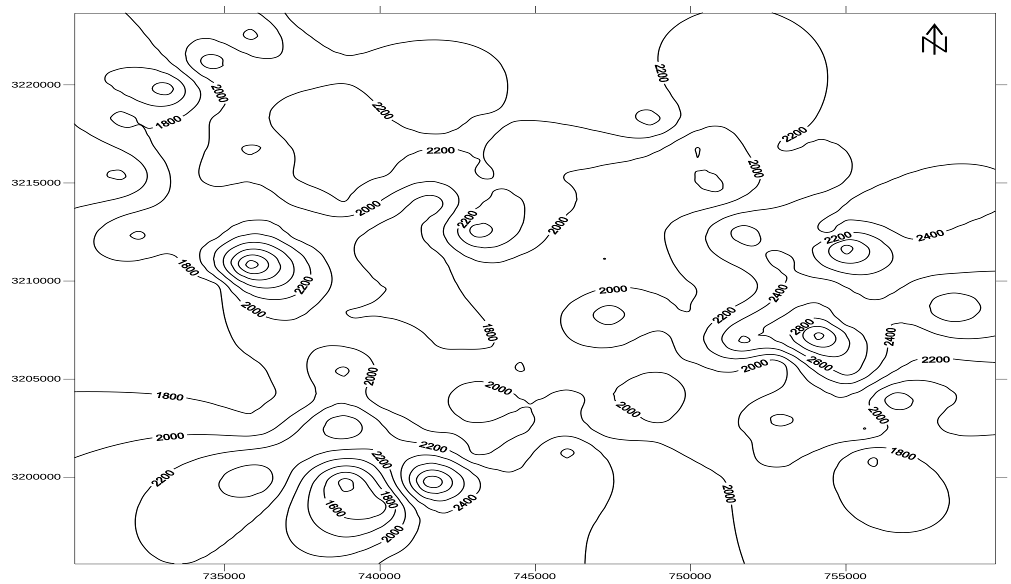
(Fig 4) Elevation contour map (contour intervals 10 m)



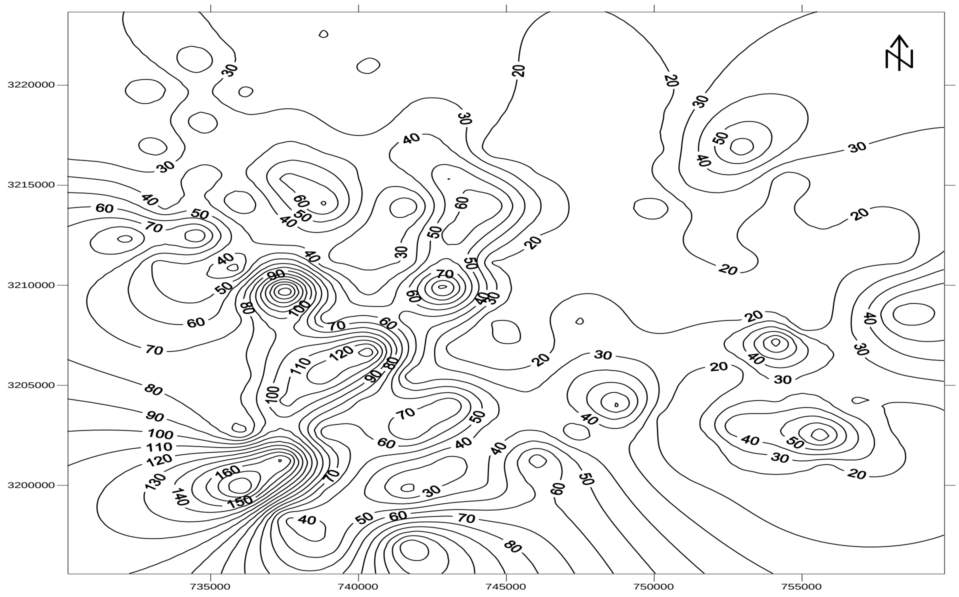
(Fig 5) velocity of seismic wave in the first layer (contour interval 200 m/s).



(Fig 6) velocity of seismic wave in the second layer (contour interval 200 m/s).



(Fig 7) velocity of seismic wave of the sub-weathering layer (contour interval 200 m/s).



(Fig 8) Thickness of the weathering layer map (contour interval 10m)

CONCLUSION

1. **1.** The weathering layer or low velocity layer (LVL) in the study area is consisting of more than one layer.
2. **2.** The first layer is an eolian sedimentary layer (loess created by wind) that covers the surface of the area. It is a thin layer ranges from 4 m to about 10 m. except for some areas where the thickness exceeds 100 m.
3. **3.** The second layer is mostly clay, the seismic wave velocity ranges from 1500 m/s to 3200 m/s it increases clearly to the southwestern part of the area.
4. **4.** The first and second layers together can be considered as a weathering layer because the velocity of seismic waves in them is extremely low in several locations and varies greatly along them.

5. The thickness of the weathering layer is clearly varied, ranging from 20m in the east part to more than 100 m in the west and southwest so it is thicker in the southwestern region.
6. The third layer is mostly mudstone its velocity ranges between 1600 m/s to 2500m/s and its thickness ranges from 20 m to more than 100 m in some locations with an average value of 50 m. This layer can be considered as a sub-weathering layer.
7. The fourth layer was reached only in some Upholes. The velocity of the seismic waves ranges in the locations in which it appeared between 2100 m/s to 2800 m/s, therefore its thickness cannot be predicted.
8. Replacement velocity was estimated at 2000 m/s. calculated from the arithmetic average of the velocities obtained from the sub weathering layer.

REFERENCES

1. Marsden, D. (1993). Static corrections—A review. The Leading Edge, 12(2), 115-120..
2. Dobrin, M. B., & Savit, C. H. (1960). Introduction to geophysical prospecting (Vol. 4). New York: McGraw-hill..
3. Agoha, C. C., Opara, A. I., Okereke, C. N., Onwubuariri, C. N., Emberga, T. T., Inyang, G. E., ... & Chilaka, J. C. (2015). Weathered layer determination and its effects on engineering structures: case study of parts of the Niger delta. World, 3(2), 40-51.
4. BGP Company 2005, Acquisition Final report of 3D seismic project, Concession 11 Ghani, Zenad, Ed dib area, Tripoli/Libya.