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دراسة طبقة التجوية باستخدام طريقة المسح السيزمي الانكساري البئري، الامتياز 72، حوض سرت – ليبيا

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Investigation into the Weathering Layer Using Up-hole Method of Seismic Refraction, Concession 72, Sirt basin- Libya

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الملخص:
في هذه الدراسة تم تحليل وتفسير معلومات المسح السيزمى الانكساري للآبار التي تسمى اصطلاحا uphole survey والمتحصل عليها من منطقة الدراسة التي تسمى الناقه En Naga area الواقعة ضمن امتياز 72 التابع لشركة فيبا للعمليات النفطية في حوض سرت. تهدف الدراسة الى إيجاد عمق طبقة التجوية وكذلك التعرف على سرعة الموجات السيزميه في الطبقات التي تتموضع تحتها لتحديد سرعة الاستبدال Replacement velocity وذلك لغرض استخدام هذه المعلومات في مرحلة التصحيحات الاستاتيكيه للمعلومات السيزميه ثلاثية الابعاد في المنطقة المشار اليها. تم حفر 39 بئرا لهذا الغرض بمتوسط عمق 200 متر تقريبا واجراء تسجيل السرود لها من القاع وحتى سطح الأرض. بينت المعلومات وجود أربع طبقات تم اختراقها بالحفر أمكن تمييزها بسهوله من خلال تباين سرعة الموجات السيزميه بينها. أُعتبرت الطبقات الثلاث العليا مجتمعه طبقات تجويه، حيث يتراوح سمكها من 150 متر إلى 206 متر تقريبا. السرعة في الطبقة الرابعة عالية نسبيًا مقارنة بالطبقات العليا وتتراوح من 1750 م/ث إلى 2750 م/ث وتظهر عدم استقرار جانبي في السرعة. بسبب عدم الاستقرار الجانبي لسرعة الموجات في الطبقة الرابعة التي تم اعتبارها طبقه تحت التجوية Sub-weathering layer لم يكن من الممكن تحديد قيمة واحده لسرعة الاستبدال Replacement velocity بسبب التباين الكبير لسرعة الموجات السيزمية بها. للحصول على تصحيح استاتيكى مقبول يوصي بأعداد نموذج متكامل للسرعة لحساب التصحيح الاستاتيكى مبنى على معلومات الأبار وكذلك المعلومات السيزمية First break method في منطقة الدراسة.
الكلمات الدالة: مسح سيزمي انكساري بئري، طبقة التجوية، الإنكسار السيزمي، التصحيح الإستاتيكي، سرعة الاستبدال السيزمية.

Abstract:
In this study, the refraction seismic survey data (uphole survey data) acquired from En Naga area, located within Concession 72, Affiliated with Veba Oil

Operations Company (V.O.O) in Sirt Basin, were analysed and interpreted. The study aims to determine the depth of the weathering layer and identify the seismic wave velocities of the sub-weathering layer to calculate the replacement velocity. This information is intended for use in the static corrections phase of the 3D seismic data carried out in the mentioned area. A total of 39 wells were drilled for this purpose, with an average depth of approximately 200 meters, and velocity logs were recorded from the bottom to the surface. The data indicated the presence of four layers penetrated by drilling, which could easily be distinguished by the variation in seismic wave velocities between them. The velocity in the fourth layer is relatively high compared to the upper layers, ranging from 1750 m/s to 2750 m/s, and it also shows lateral velocity instability. The upper three layers combined were considered weathering layers, with a thickness ranging from 150 meters to approximately 206 meters. Due to the lateral velocity instability in the fourth layer, which was considered the sub-weathering layer, it was not possible to determine a single value for the replacement velocity. An integrated velocity model is recommended to calculate the static correction based on well information in addition to seismic information (First break method) in the study area.

Keywords: Uphole survey; Weathered layer; Seismic refraction; Static correction; Replacement velocity.

1. 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.

The seismic refraction method is a geophysical technique used to determine thickness of weathered layers, depth to bedrock, depth of the water table and other seismic velocity boundaries. For the seismic refraction method to be used effectively, subsurface determination, the travel times of the generated wave and the offset distance must be determined. It requires a drilling rig, pulley, and water tank and man power and takes some time for the drilling process. It measures the travel times of primary and secondary waves from the energy source to the receivers. It also provides near surface information at the point of survey about the lithology of lateral formations. In uphole refraction, the survey is performed in a single borehole in that a hole is drilled to the required depth at the survey location and a vibrating source is created to determine the velocity for various soil layers. (Omenikolo et al .2013).

2. Background of uphole method

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: An Uphole survey). The arrival times and 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, to obtain values for static correction to be used in the processing of reflection data for 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).

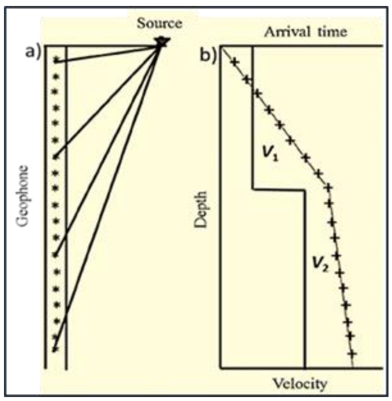

Figure 1: An Uphole survey (a) Field layout. (b) Corrected first break times (+) and derived velocity (solid line).

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 (Aminzateh et al. 2013).

3. 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.

3.1 Location and topography

Arab Geophysical Exploration services company contracted with Veba Oil Operations (V.O.O.) in 1996 to undertake 3D land seismic survey in concession 72, En Naga area (Currently known as Area 120) .En Naga area is situated 200 km south of Zalla village on the Zalla to Tazerbo track. *(Fig 2: 3D seismic survey location map).* Most of the terrain consists of a rolling sand/gravel surface interspersed with many rocky ridges and small jebels. Towards the south eastern portion of the area is a broad ridge of basalt which is exposed on the surface. An uphole seismic refraction survey was carried out in conjunction with the seismic survey. The elevation of the area ranges from 280 m to 328 m above sea level *(Fig 3: Elevation contour map).* (Arab geophysical exploration services company.1993).

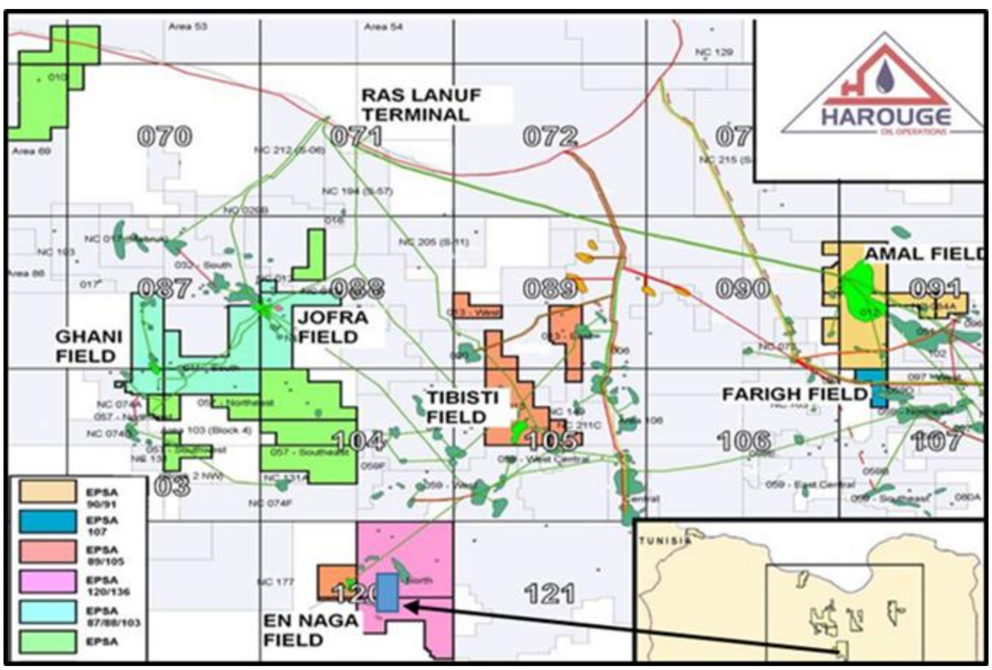

Figure 2: 3D seismic survey location (V.O.O, 1996). An uphole seismic refraction survey was carried out conjunction with the seismic survey. The total project area is estimated at 150km², (Map not to scale)

4. Data collection and analysis

In 1996, a total of 39 Uphole locations were drilled and logged by Arab geophysical exploration services company , the Uphole locations are shown in (Fig 4: Uphole location map). The target depth of Upholes in the area was dependent on surface elevation. Uphole depths were calculated for each hole individually to obtain six shots below the weathering layer. Previous work in the area showed that the bottom of the weathering was consistently around 165-190 m AMSL elevation. The Upholes were drilled on receiver lines and spaced approximately every three kilometers. For source of energy, hammer-plate combination was used, placed 3 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. The bottom of the hole logged at 2.5 m intervals to ensure the final velocity is accurately determined, 12 points were recorded, in the shallow depth from 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 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).

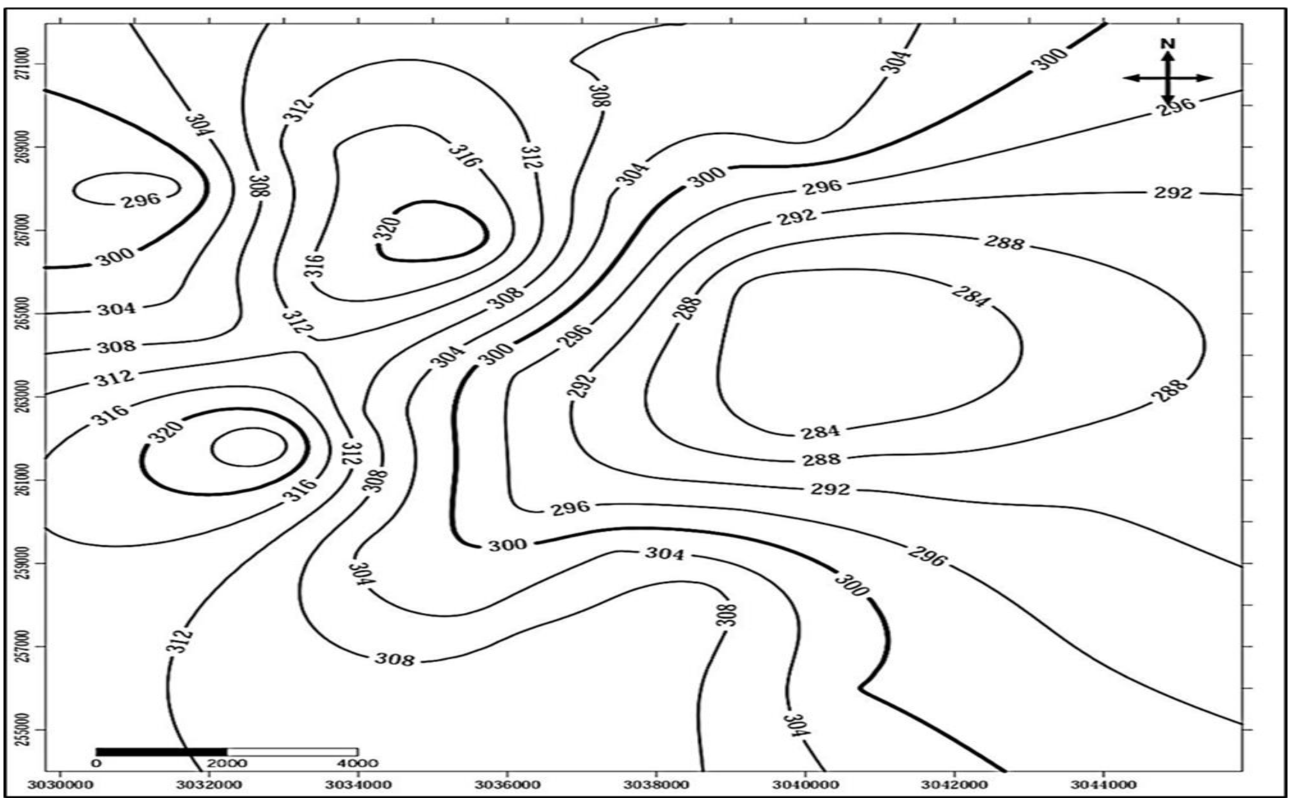

Figure 3: Elevation contour map (contour intervals 4 m)

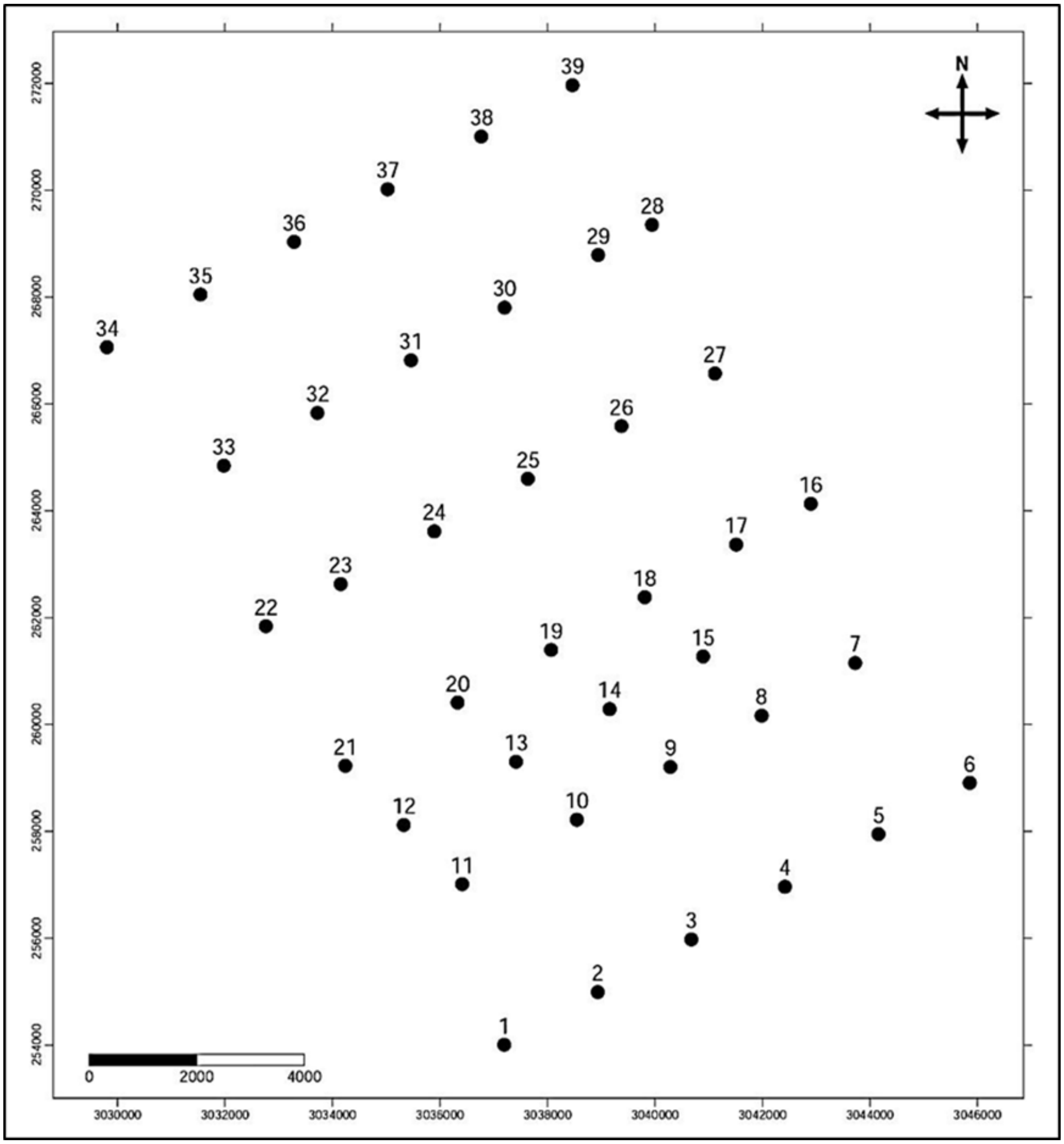

Figure 4: Upholes locations map

Table 1: Elevation of Upholes location Z (m), Velocities of drilled layers V (m/s) and thickness of penetrated layers H (m).

Northing	Easting	Z	Uphole	V1	H1	V2	H2	V3	H3	V4
3037195	254005	311	1	650	12	1059	80	1210	86	1957
3038936	254991	307	2	688	7.5	1113	103	1403	68	2290
3040677	255976	300	3	626	28	1100	96	1355	49	2195
3042418	256962	298	4	630	8.5	1071	62	1272	104	2105
3044159	257947	294	5	600	11	1122	99	1250	57	2288
3045857	258908	292	6	357	2.5	862	58	1114	100	1892
3043726	261150	291	7	714	35	1043	111	1400	34	2308
3041985	260165	293	8	538	5	746	15	1105	130	1835
3040287	259204	299	9	505	10	1120	112	1295	54	2380
3038546	258218	310	10	653	24	1138	111	1267	55	2678
3036413	257011	310	11	555	5	953	47	1136	99	1826
3035326	258119	302	12	403	2.5	902	67	1264	109	2000

3037415	259302	304	13	455	2.5	840	47	1166	133	2258
3039156	260287	296	14	462	9	1100	101	1176	61	2069
3040897	261273	290	15	719	31	1024	29	1273	103	2282
3042900	264131	284	16	520	2.5	841	40	1138	119	1830
3041511	263367	281	17	595	2.5	809	22	1091	132	2228
3039810	262382	282	18	646	7.5	879	29	1150	126	2740
3038069	261396	290	19	532	10	1046	96	1477	69	2353
3036328	260411	295	20	714	27	1031	79	1241	59	2343
3034239	259228	302	21	514	7.5	774	36	1208	136	2011
3032761	261840	328	22	424	2.5	978	71	1232	111	1925
3034153	262628	307	23	688	15	896	45	1264	119	2703
3035894	263614	297	24	455	2.5	850	47	1273	115	1935
3037635	264599	292	25	490	4	720	32	1210	138	2500
3039376	265585	282	26	291	2.5	916	97	1428	65	2222
3041117	266570	286	27	644	11	913	37	1167	111	2222
3039944	269354	306	28	510	2.5	1552	20	1186	135	1800
3038943	268788	301	29	862	5	1048	71	1325	110	2174
3037202	267802	305	30	455	4	1084	83	1268	95	1748
3035461	266817	323	31	1470	24	1000	46	1176	131	2476
3033720	265831	319	32	676	6	1089	62	1268	131	2273
3031979	264845	305	33	320	2.5	1003	114	1429	66	2148
3029804	267063	297	34	763	10	962	47	1139	110	2632
3031545	268048	295	35	455	2.5	792	22	1128	146	2308
3033286	269034	315	36	500	3.5	1338	141	1065	57	1800
3035027	270019	315	37	466	3.5	1502	46	1223	155	2000
3036768	271005	308	38	667	4	1045	61	1263	124	1974
3038465	271966	308	39	581	2.5	1081	71	1234	116	1875

5. Results and discussion

In many exploration areas, the near-surface or weathering layer is covered by a relatively thin and uniform low-velocity layer; however, this is often not the case. Common near-surface conditions include, but are not limited to, elevation changes, sand dunes, and eolian deposits, all of which present potential challenges. The presence of low- or high-velocity layers alone does not pose problems; rather, the issues arise due to variability in both the thickness and velocity of these near-surface layers, and our ability to adequately define or compensate for these variations.

Previous work in the area showed that the base of the weathering consistently lies around 165-190 meters above mean sea level (AMSL). The weathering layer was found to be relatively uniform across the area.

The weathering layer, or low-velocity layer (LVL), in the study area consists of more than one layer. Data obtained suggest a model of four layers, with notable variation in seismic wave velocities between them.

1. The first layer is loess sand deposited by wind, covering the surface of the area (surface layer). Its thickness varies significantly, ranging from 2 m to 35 m in some locations, and it barely shows up in the relationship curves. The first layer conforms entirely to the topography, with slightly increased thickness in low-lying areas. Seismic wave velocity in this layer is very low, in some places nearly matching the

velocity of seismic waves in the air, ranging from 350 m/s to over 1000 m/s (Fig. 5: Seismic wave velocity in the first layer).

2. The second layer is primarily clay, with thicknesses ranging from 20 m to 140 m in some areas. Compared to the first layer, the second layer is more homogeneous in terms of seismic wave velocity, though it still exhibits notable lateral variation, with velocities ranging from 700 m/s to 1500 m/s (Fig. 6: Seismic wave velocity in the second layer). The seismic velocity behavior in the second layer resembles that of the first layer, though thickness variations are more pronounced.

3. The third layer consists mainly of sandstone mixed with clay, showing minimal difference from the layer above in terms of velocity, yet the rapid lateral changes in seismic velocity remain clearly visible. The velocity in this layer ranges from 1065 m/s to 1400 m/s, with thicknesses ranging from 34 m to 155 m in some areas (Fig. 7: Seismic wave velocity in the third layer).

4. The fourth layer was penetrated only to a limited extent in all Uphole locations, as drilling did not reach its base; therefore, its full thickness cannot be determined. Drilling was halted at this layer, which was considered a sub-weathering layer. The velocity in the fourth layer ranges from 1750 m/s to 2750 m/s, which is relatively high compared to the upper layers and shows lateral instability (Fig. 8: Seismic wave velocity in the fourth layer). This lateral instability may complicate static correction if a single replacement velocity is used in the processing stage.

The total thickness of the weathering layer is the combined thickness of the upper three layers, ranging from 150 m to 206 m (Fig. 9: Thickness of the weathering layer map).

Overall, analysis of the Uphole data indicates that the weathering layer extends deeper than the depth of the Upholes, as the fourth layer does not exhibit the desired consistency in lateral velocity and thickness.

Static corrections are crucial in the seismic processing of land data as they improve the quality of subsequent processing steps, which in turn impacts the integrity, quality, and resolution of the imaged section. Errors in static correction can result in a loss of both temporal and spatial seismic resolution. Furthermore, if static corrections are not accurately derived, a range of issues may arise for the interpreter, such as lines with variable datum, seismic events that mistie at intersections, false structural anomalies in the data, noise-induced false events, and suboptimal data quality. Therefore, achieving an accurate static correction solution is essential for two reasons: obtaining a correct structural interpretation and producing a high-resolution section suitable for stratigraphic interpretation.

The times that must be removed from the seismic recordings include the time for the weathering layer (obtained from Uphole surveys) and the time for the sub-weathering layer, calculated using the replacement velocity.

Upholes are primarily drilled to reach the sub-weathering layer to measure its velocity. Since the velocity of seismic waves in the sub-weathering layer is generally more stable than in the layers above, it can provide a basis for static correction. However, if the study area is extensive, with probable lateral velocity variations or significant lateral variability in the sub-weathering layer, multiple replacement velocities may be necessary to achieve accurate static correction results.

Replacement velocity is used to calculate the time adjustments needed to normalize seismic data to a horizontal reference, typically sea level or another defined level, and to remove topographic effects. The velocity used should closely approximate the sub-weathering layer velocity to ensure accurate static corrections.

In the study area, it is not feasible to use a single replacement velocity due to the factors mentioned above. Instead, a complete velocity model should be employed to calculate the static correction. Additional seismic data, such as refracted waves (first break method), can also be used to enhance accuracy. The first break method, which involves detecting the first arrivals of refracted energy from the base of the weathering layer, serves as a valuable supplement or sometimes an alternative to Uphole data. The first break analysis can provide insights into the deeper layers.

These procedures should be tested during the seismic data processing phase to determine which methods yield the most accurate results, or whether a combination of both should be used for the best approach.

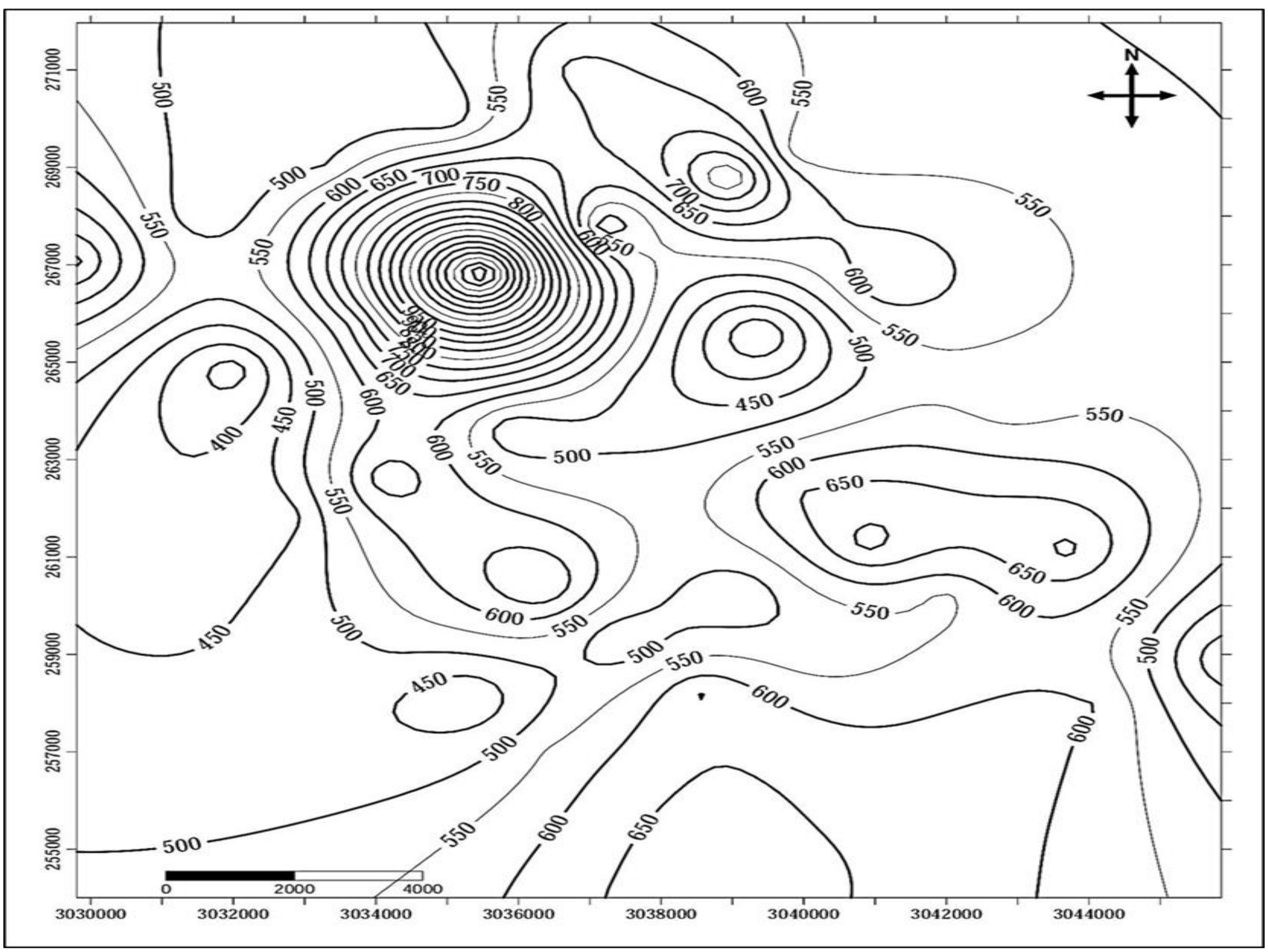

Figure 5: velocity of seismic wave in the first layer (contour interval 50 m/s).

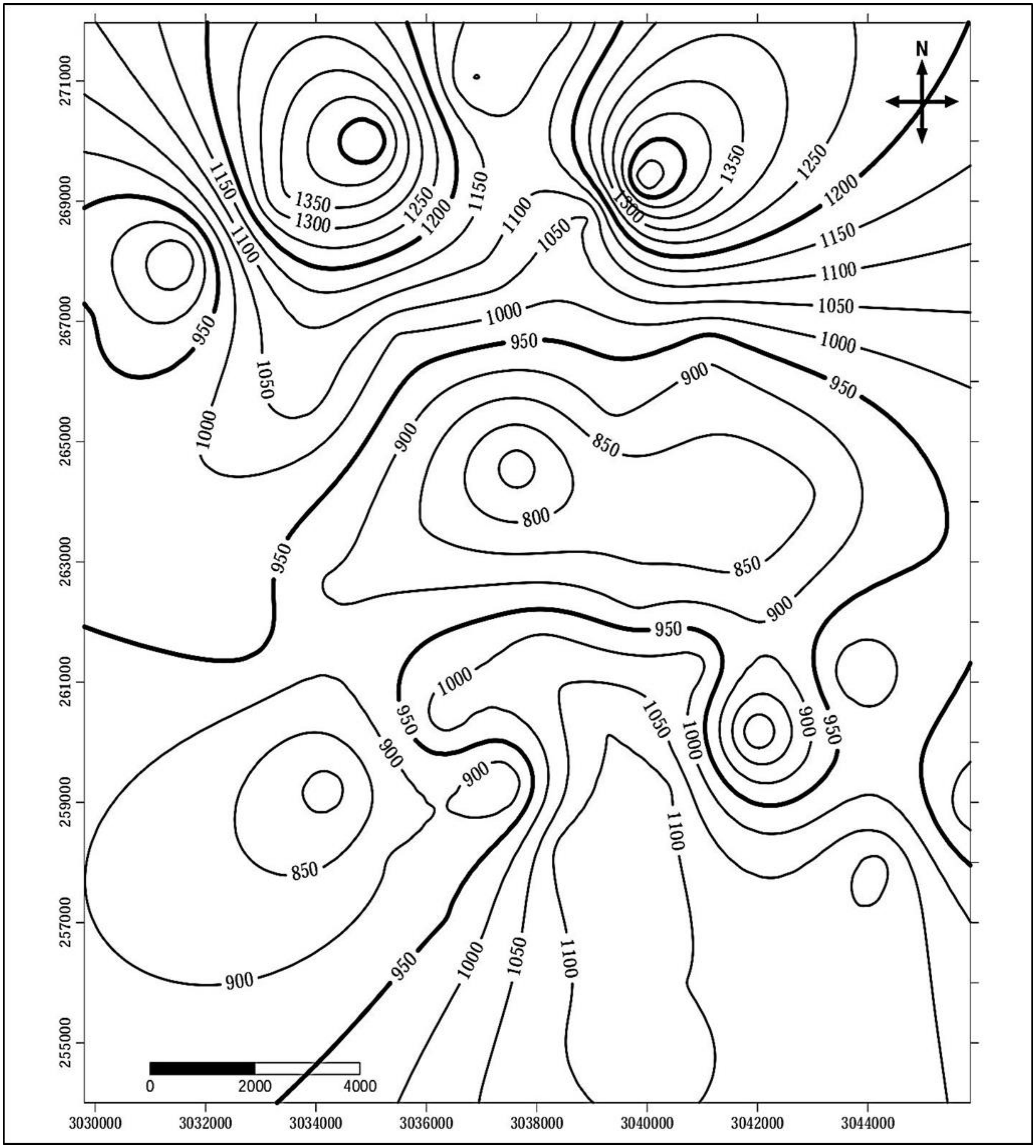

Figure 6: velocity of seismic wave in the second layer (contour interval 50 m/s).

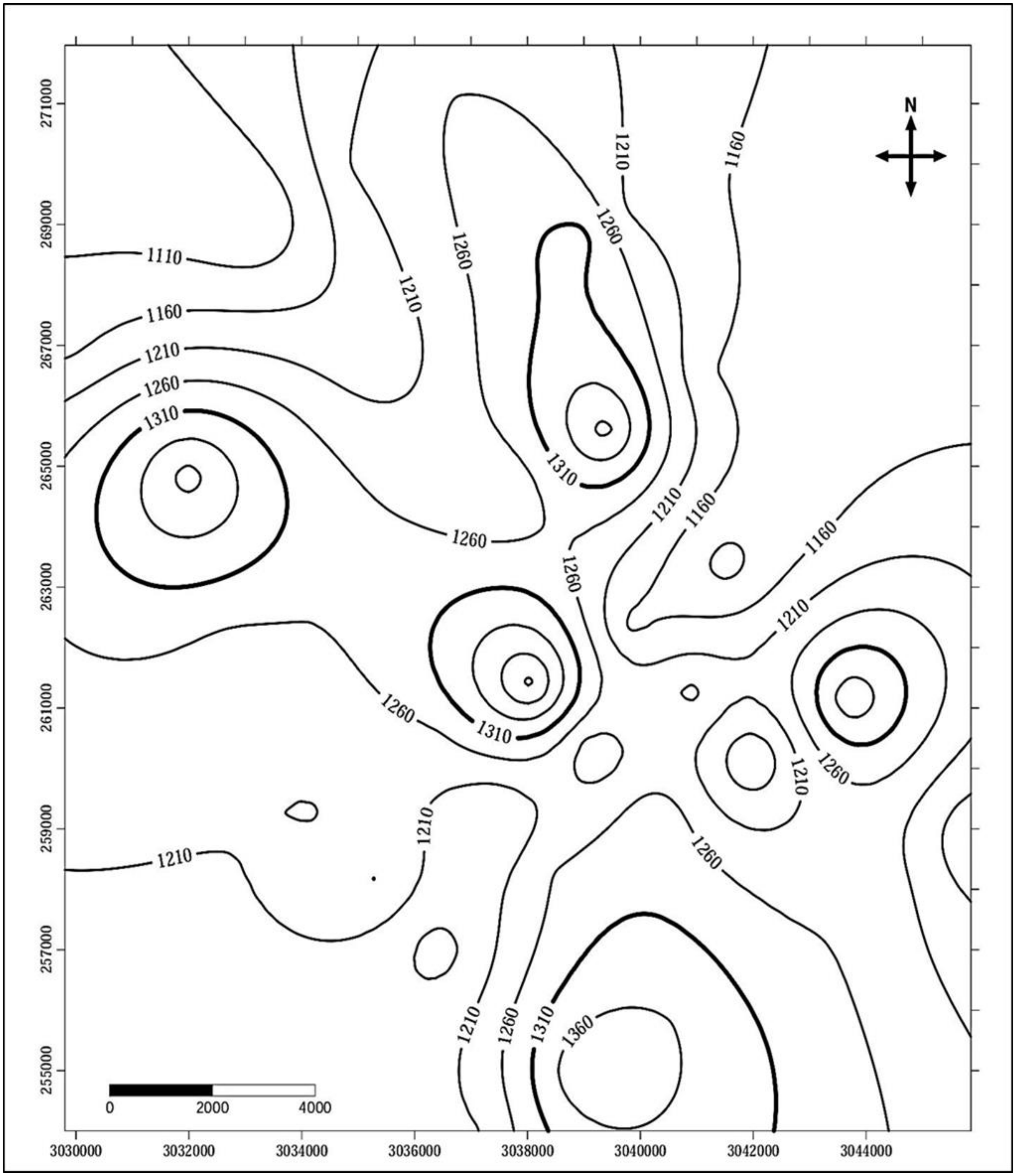

Figure 7: Velocity of seismic wave in the third layer (contour interval 50 m/s).

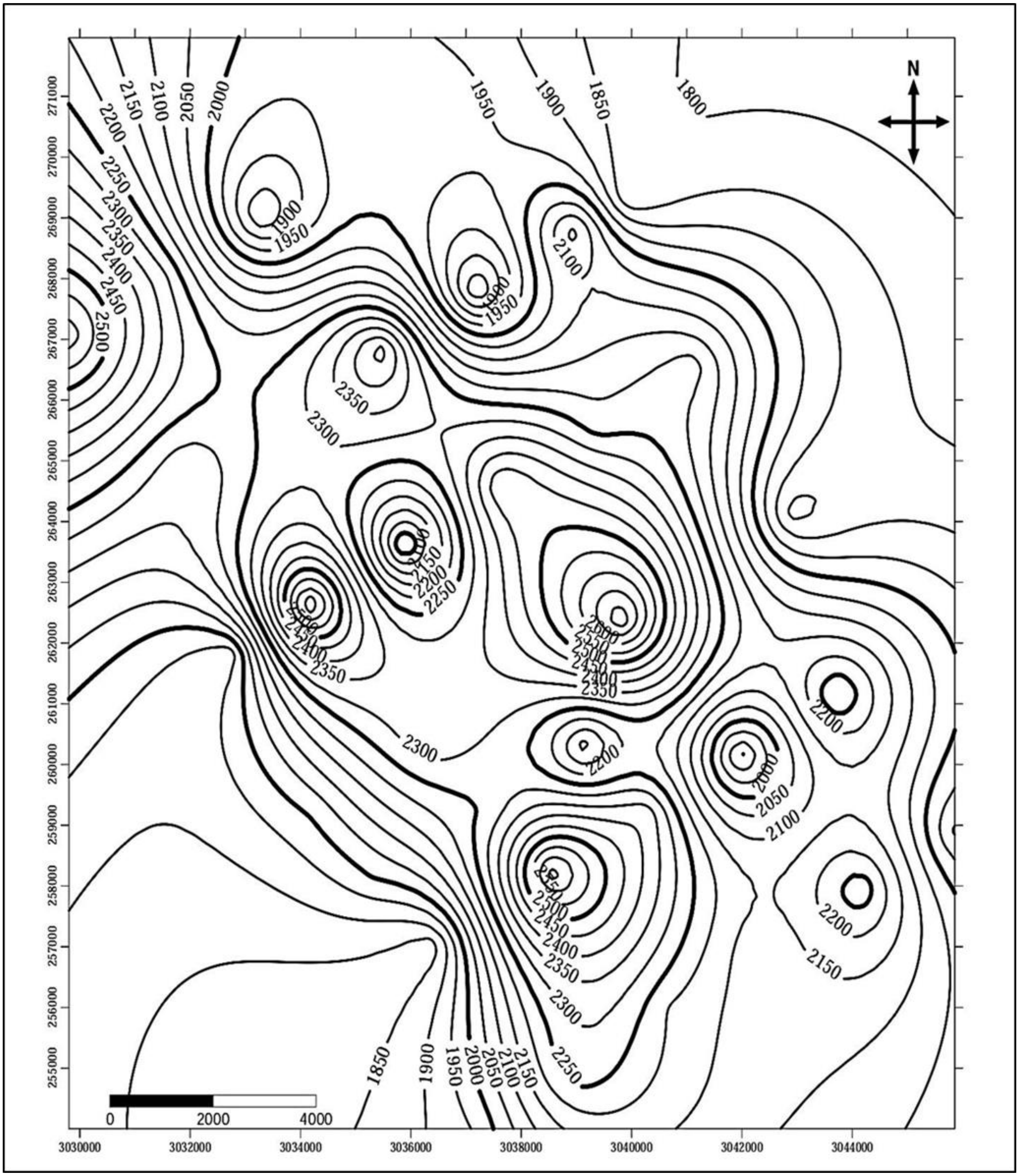

Figure 8: velocity of seismic wave of the sub-weathering layer (contour interval 200 m/s).

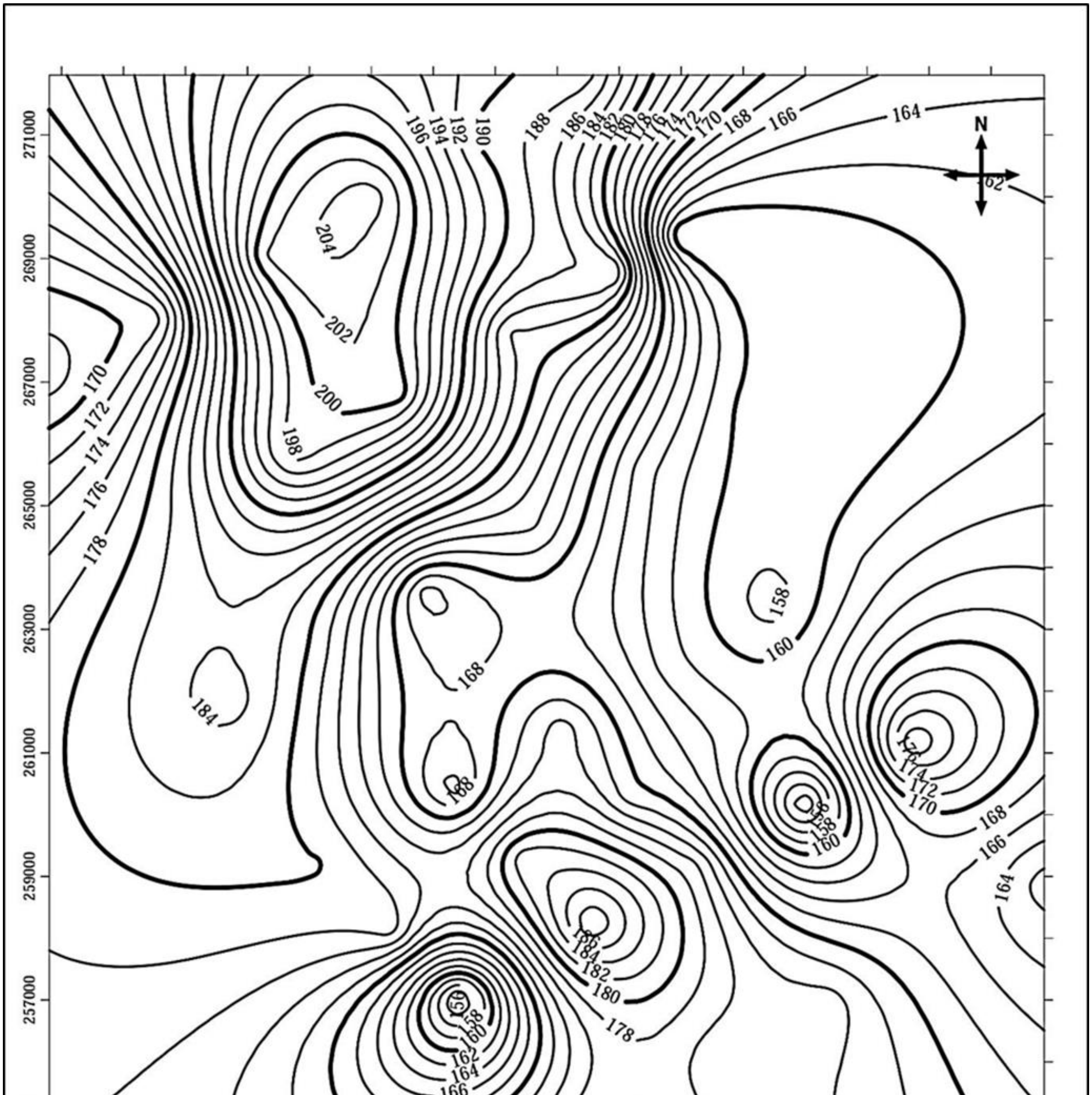

Figure 9: Thickness of the weathering layer map (contour interval 2m)

6. Conclusion

1. The weathering layer or low velocity layer (LVL) in the study area is consisting of more than three layers.
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 2 m to 35 m. except for some areas. Seismic wave velocity ranges from 350 m/s to more than 1000 m/s.
3. The second layer is mostly clay, thickness ranges from 20 m to 140 m. Seismic wave velocity ranges from 700 m/s to 1500 m/s.
4. The third layer is mostly sand stone contaminated with clay, thickness ranges from 34 m to 155 m. Seismic wave velocity ranges from 1065 m/s to 1400 m/s.
5. The thickness of fourth layer cannot be predicted. Drilling stopped at this layer and it was considered a sub-weathering layer. The velocity within this layer relatively high compare with upper layers and unstable laterally, ranges from 1750 m/s to 2750 m/s.
6. The upper three layers can be considered collectively as weathering layers, and the fourth layer will be the sub-weathering layer.
7. The thickness of the weathering layer is the summation of the thickness of the upper three layers, and it ranges between 150m to 206m.
8. It is clear that the weathering layer in the study area is deeper than the depth to which the Upholes were drilled.
9. Complete velocity model should be used to calculate static correction.
10. First break method should be used for more accurate results.

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