Hawke’s Bay 3D Aquifer Mapping Project:
Interpretation of key boreholes in the Ruataniwha Plains

June 2023

Hawkes Bay Regional Council Publication No. 5615

HAWKES BAY
REGIONAL COUNCIL
TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

ISSN 2703-2051 (Online)
ISSN 2703-2043 (Print)

HAWKES BAY
REGIONAL COUNCIL
TE KAUNIHERA Ā-ROHE O TE MATAU-A-MĀUI

(06) 835 9200
0800 108 838
Private Bag 6006 Napier 4142
159 Dalton Street . Napier 4110

Environmental Science

Hawke's Bay 3D Aquifer Mapping Project:
Interpretation of key boreholes in the Ruataniwha Plains

June 2023
Hawkes Bay Regional Council Publication No. 5615

Prepared By:
GNS Science
RL Kellet ZJ Rawlinson M Herpe

For: Hawke's Bay Regional Council

Reviewed by:
S Harper, Hawke's Bay Regional Council
MJ Arnot, GNS Science
C Tschritter, GNS Science

ISSN 2703-2051 (Online)
ISSN 2703-2043 (Print)

.

1 Fairway Drive, Avalon
Lower Hutt 5011
PO Box 30368
Lower Hutt 5040
New Zealand
T +64-4-570 1444
F +64-4-570 4600
www.gns.cri.nz

22 June 2023

Team Leader – Hydrology and Groundwater Science
Hawke's Bay Regional Council
Private Bag 6006
Napier 4142

Attention: Simon Harper

Dear Simon,

Hawke's Bay 3D Aquifer Mapping Project: Interpretation of Key Boreholes in the Ruataniwha Plains

1.0 SUMMARY AND CONCLUSIONS

The area of the Ruataniwha Plains covered by the SkyTEM survey includes 654 boreholes with lithological information (WellStor database, accessed February 2021). The average depth of these boreholes is less than 50 m, so the majority of the boreholes only constrain the shallow part of the basin. This project utilises a subset of those boreholes that contain detailed geological and geophysical data, including: three petroleum boreholes, 11 boreholes drilled as part of previous groundwater research projects and two boreholes drilled as part of the Hawke's Bay 3D Aquifer Mapping Project (3DAMP). The first focus of the project was to assess the variation in geology around the two 3DAMP boreholes. The second focus of the work was to look at areas of the Ruataniwha Plains with good borehole control and identify trends in the geological units. The third focus of the work was to provide borehole-based support for the mapping of the top of the hydrogeological basement with the SkyTEM data (Sahoo et al. 2023). There is a strong correlation between the SkyTEM resistivity model(s) and the geological units identified in the boreholes. Additional data from GroundTEM soundings and seismic lines have been used to develop a laterally mappable stratigraphy that comprises:

- Alluvial and fan deposits: gravel and sand (Holocene: Young Gravel).
- Alluvial and fan deposits: gravel and sand (Pleistocene: Salisbury Gravel).
- Fluvial deposits: clay, silt and ash (Late Pleistocene: Kidnappers Group).
- Marine deposits: siltstone, mudstone and limestone (Upper Pliocene: Mangaheia Group).

The two 3DAMP boreholes provide constraints on the Holocene and Pleistocene formations and correlate well with adjacent boreholes. The Young Gravel unit is well-defined and has high resistivity. The Salisbury Gravel is variable in resistivity and has a poorly defined base. Hydrogeological basement is defined across the study area as Undifferentiated Late Pleistocene or Upper Pliocene Limestone / Mangaheia Group sediments (Sahoo et al. 2023).

2.0 INPUT DATA

A thorough review of the geology, hydrogeology and available data and models in the Ruataniwha Plains SkyTEM survey area was provided in Tschritter et al. (2022). The detailed geological interpretation presented herein utilised 15 high-quality boreholes and supporting geophysical data, including:

1. Detailed data from two boreholes drilled as part of 3DAMP (Lawrence et al. 2022a, 2022b).
2. Lithological data from five high-quality boreholes from the Hawke's Bay Regional Council (WellStor) database.
3. Detailed data from three petroleum boreholes (Leslie 1971a, 1971b; Johnston and Langdale 2000).
4. Detailed data from five research boreholes (Brown 2002).
5. SkyTEM-derived smooth and sharp resistivity models (Figure 2.1; Rawlinson et al. 2022).
6. GroundTEM soundings available in the area (Tschritter et al. 2022).
7. Seismic data interpretations (Figure 2.1; Tschritter et al. 2022).

The 15 boreholes are located primarily in the eastern and southern parts of the Ruataniwha Plains (Figure 2.1).

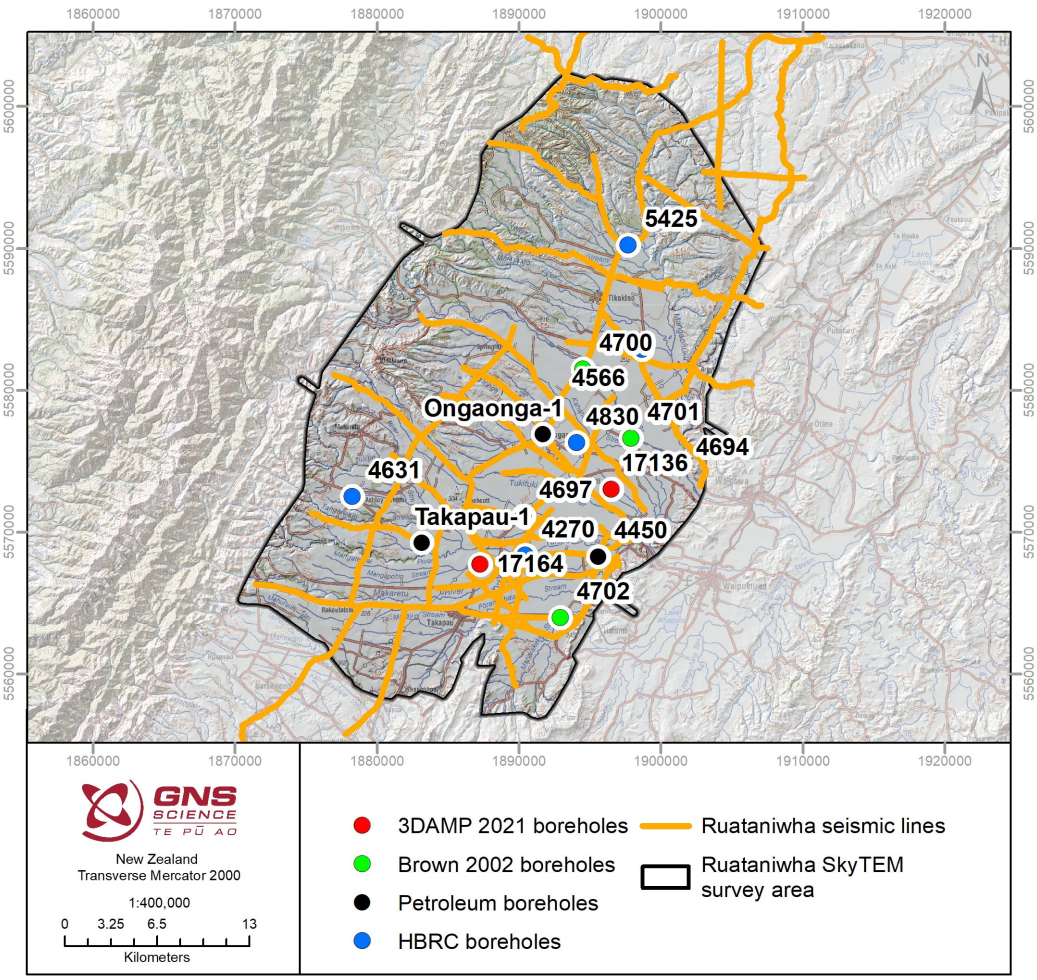


Figure 2.1 Location map of the Ruataniwha Plains showing the extent of the Ruataniwha SkyTEM survey area, as well as the location of the boreholes and seismic lines. Speedy-1 is drilled at the same location as 4450.

3.0 METHOD

3.1 Borehole Interpretation

The data for each borehole have been compiled into a standard borehole sheet; these are attached as supplemental material. Each borehole was interpreted using the following geological and geophysical data:

- Primary lithology (all boreholes).
- Percentage of each grain-size component (all boreholes).
- Description of lithological units, including stratigraphy (all boreholes).
- Borehole geophysical logs (two 3DAMP and two petroleum boreholes).
- Smooth and sharp SkyTEM models (all boreholes).
- GroundTEM models (8 boreholes).
- Seismic reflection sections (10 boreholes).

The primary lithologies for the unconsolidated section were characterised as clay, silt, sand, gravel, volcanic, organic, shells or fill. For boreholes that penetrated the Pliocene interval, such as the three petroleum boreholes, additional primary lithologies included mudstone, siltstone, sandstone and limestone. The sampling intervals varied from 1 m to 10 m depending on the type of borehole. The percentages of each lithology in each sample interval were estimated based on the detailed descriptions. For the petroleum boreholes, the data were digitised from the composite log (Leslie 1971a, 1971b; Johnston and Langdale 2000). For all other boreholes, most descriptions included a dominant lithology (75%), with indications of minor (10–15%) and trace (5%) amounts of other grain sizes.

The description of the units in terms of age, or formation name, utilises the stratigraphy developed by Francis (2001) and summarised in Tschritter et al. (2022).

3.2 Geophysical Logs

Borehole geophysical logs are available in the two boreholes drilled as part of 3DAMP (Lawrence et al. 2022a, 2022b) and the petroleum boreholes Ongaonga-1 and Takapau-1 (Leslie 1971a, 1971b). In the petroleum boreholes, the natural gamma log and rate of penetration (ROP) data provide some estimate of the clay content and the degree of lithification of the recent and Pleistocene sediments. In the 3DAMP boreholes, the density logs provide some additional information on the porosity in the unconsolidated units. Resistivity logs, which can be directly correlated with the SkyTEM data, are only available in the deeper sections of the petroleum boreholes Ongaonga-1 and Takapau-1.

3.3 SkyTEM and GroundTEM Models

The SkyTEM line closest to each borehole is used to provide a single sounding that is representative of the resistivity structure at the borehole. Both the smooth inversion and sharp inversion models are included in the analysis (Rawlinson et al. 2022). The models extend to 500 m depth, but the Depth of Investigation (DOI) is typically at 150–300 m depth at most sites. The GroundTEM data are available at the two 3DAMP boreholes (17136 and 17164), at five of the boreholes from the Brown (2002) study and at one from an older Hawke’s Bay Regional Council borehole.

3.4 Seismic Sections

The seismic reflection data collected for the petroleum exploration industry (Figure 2.1) are useful for illustrating the lateral changes in the strata around the boreholes. The details of the seismic lines are given in Tschritter et al. (2022). The seismic data for a 400 m section of line that is closest to the borehole are shown on each composite plot (supplemental material). The data show that the top 100–150 m of the seismic lines have low reflectivity, partly due to the way that the data are acquired (frequency content and geophone spacing) and partly due to lack of strong velocity and density changes in the unconsolidated Holocene sediments. The top of the Upper Pliocene units is typically the first strong reflector, which is a consolidated mudstone, siltstone or limestone unit.

4.0 RESULTS

The first focus of the project was to assess the variation in geology around the two 3DAMP boreholes (Lawrence et al. 2022a, 2022b) using the nearby boreholes and geophysical data. The second focus of the work was to look at several specific areas of the Ruataniwha Plains with good borehole control and identify trends in the geological units. The third focus of the work was to provide borehole-based support for the mapping of the top of the hydrogeological basement with the SkyTEM data (Sahoo et al. 2023). Figure 4.1 shows the locations of the sections shown in Figures 4.2–4.5.

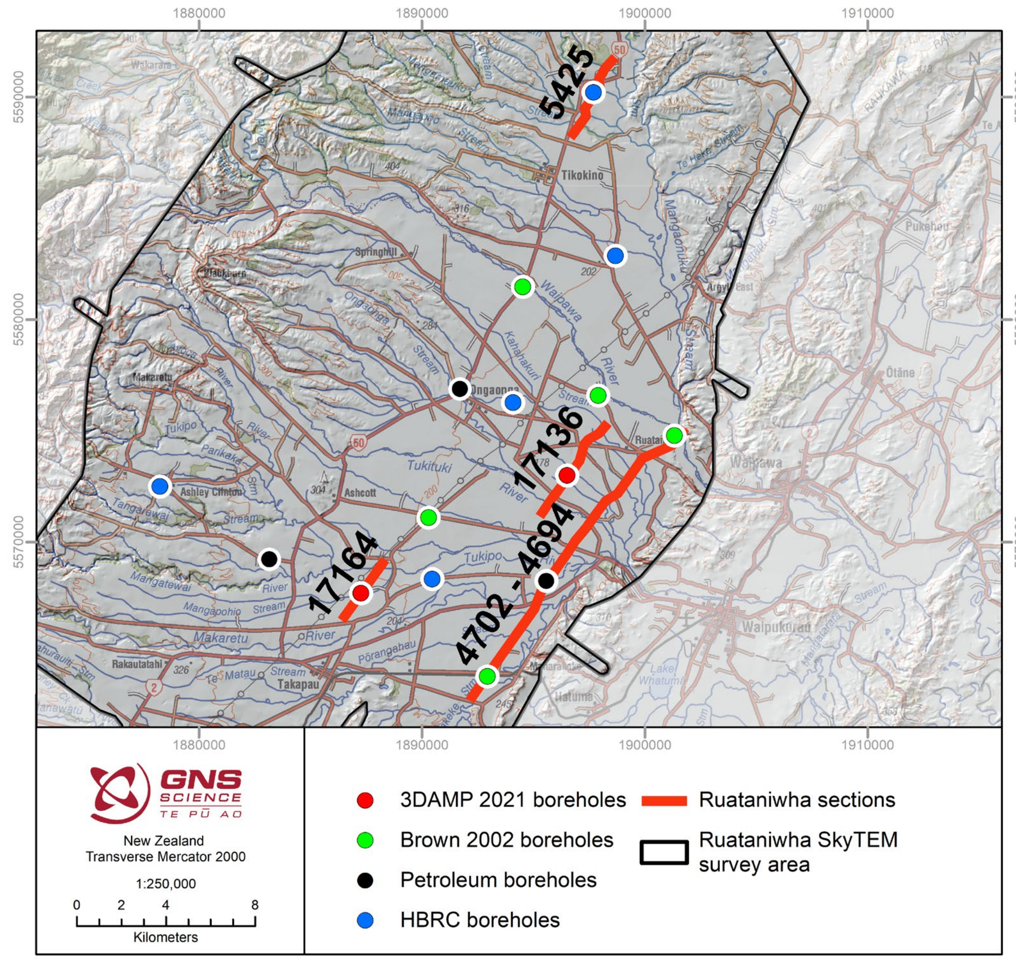


Figure 4.1 Location map of the Ruataniwha Plains showing the locations of the sections that have been extracted from the SkyTEM models at boreholes 17136, 17164, 5425, 4702, Speedy-1 and 4694.

4.1 3DAMP Borehole Correlation

4.1.1 Borehole 17136

Borehole 17136 (3DAMP Borehole 1) is located between the Tukituki and Waipawa Rivers, approximately 5 km southeast of Ongaonga (Figure 2.1). The borehole was drilled to a depth of 168 m. Two key boreholes, 4830 and Ongaonga-1, in addition to Borehole 17136, are used to help assess the thickness and extent of stratigraphy in this area. Ongaonga-1 is located 6 km west of Borehole 17136 and provides information to a depth of 1573 m. Borehole 4830 lies on a transect between these two boreholes and was drilled to a depth of 137 m. The Young Gravel unit in boreholes 17136 and 4830 is thick (~50 m), and the SkyTEM and GroundTEM resistivity models indicate that it is a continuous layer of greater than 200 ohm.m. The base of the Young Gravel unit at this location is sharp.

At Ongaonga-1, the Young Gravel deposits are mapped as being 50 m thick in the drill cuttings, but the SkyTEM resistivity model indicates that the resistive layer has thinned to 20 m and the base has transitioned gradually to a lower resistivity unit that likely contains more silt or clay. The gradual increase in gamma ray response in the borehole confirms that the fine-grained content is increasing with depth. The low resistivity layer is laterally continuous to the north and south but pinches out to the east and is not present at boreholes 4830 or 17136.

At Ongaonga-1, the top of the Salisbury Gravel is a thick ash deposit (Potaka Ignimbrite). The lower part of the Salisbury Gravel is dominated by gravel with a few thinner tephra layers. The resistivity increases to a depth of 75 m, then shows a gradual decrease to the top of the Undifferentiated Late Pleistocene sand and silt deposits. The Salisbury Gravel at Borehole 17136 is composed of interbedded gravel and sand with minor amounts of silt and organic matter. The resistivity of samples from the gravel is high, but the average resistivity of the unit is lower than the Young Gravel unit above.

A cross-section through the SkyTEM resistivity model (Figure 4.2) shows a thick layer of high-resistivity Young Gravel (150–200 ohm.m) that extends from southwest of the borehole to the northeast as a continuous layer. The base of this unit is sharp, and the resistivity drops from 150 ohm.m to less than 100 ohm.m. The layer beneath the Young Gravel is the Salisbury Gravel, and it has a resistivity that ranges from 100 to 30 ohm.m.

The Undifferentiated Late Pleistocene units at the base of boreholes 17136 and 4830 are sand and clay layers up to 20 m thick, with increasing shell content and minor tephra layers. At Ongaonga-1, this unit is given an age of Nukumaruan (Wn) or Early Pleistocene (Leslie 1971a) and is marked by a series of strong seismic reflectors. The top of the consolidated mudstone is at 200 m depth, and the first limestone unit is picked at 270 m depth. The SkyTEM resistivity increases slightly at this depth. At Borehole 4830, the same increase in resistivity and strong seismic marker is at 340 m depth, well below the depth of the borehole (137 m). Francis (2001) described this unit as the Upper Pliocene Limestone. At Borehole 17136, the SkyTEM resistivity model indicates that the limestone (>80 ohm.m) is less than 50 m below the bottom of the borehole (Figure 4.2). The seismic line closest to the borehole shows the onset of strong reflectivity at 150 m depth, marking the top of the Upper Pliocene. This seismic reflector corresponds to the increase in resistivity and increase in sand content in Borehole 17136 at 150 m depth.

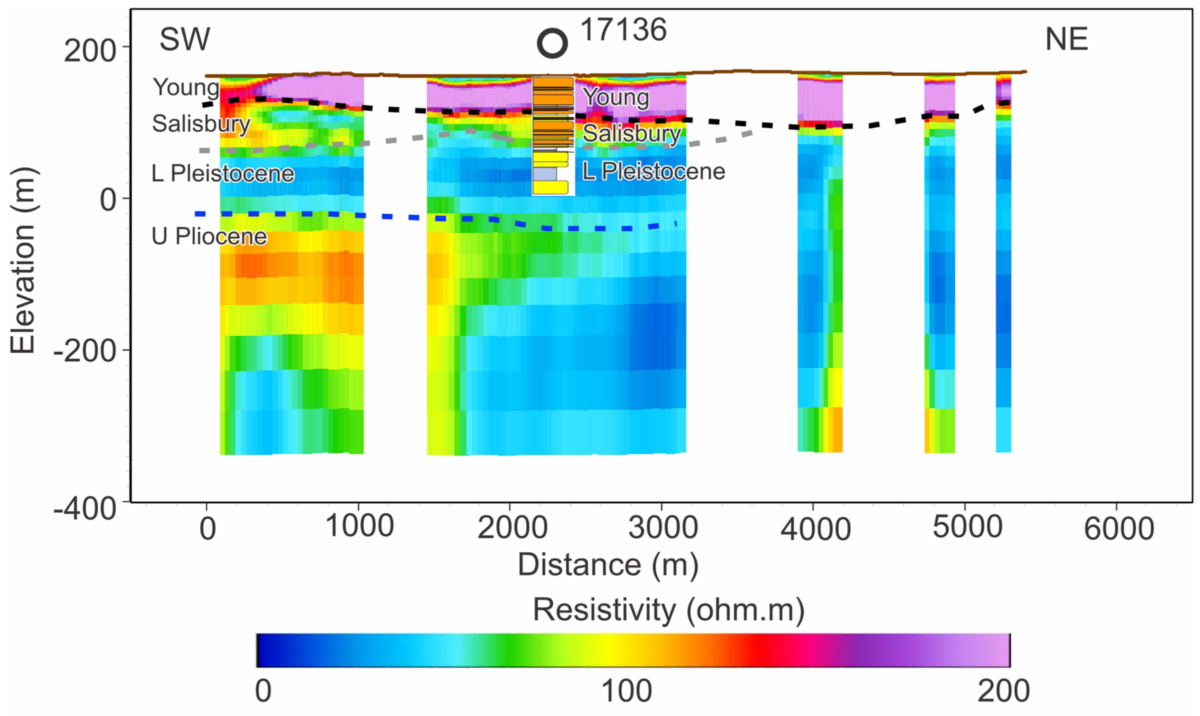


Figure 4.2 SkyTEM section through Borehole 17136 showing the variation in resistivity between the Young Gravel, Salisbury Gravel and Undifferentiated Late Pleistocene units. The location is shown in Figure 4.1. Vertical scale is 5:1.

4.1.2 Borehole 17164

Borehole 17164 (3DAMP Borehole 1) is located between Tukipo River and Makaretu Stream, approximately 4 km north of Takapau (Figure 2.1). Boreholes 4270 and Takapau-1, along with Borehole 17164, were used to help assess the thickness and extent of stratigraphy within the area. Borehole 4270 is located 3 km east of Borehole 17164, and Takapau-1 lies further to the west. Boreholes 17164, 4270 and Takapau-1 extend to depths of 74 m, 307 m and 1059 m, respectively.

A similar pattern of a high-resistivity Young Gravel layer overlying a lower-resistivity Salisbury Gravel is seen in these three boreholes. At Borehole 4270, the Young Gravel unit is 40 m thick but reduces to 15–20 m thickness at Borehole 17164 (Figure 4.3). Based on the borehole data, the Salisbury Gravel is dominated by gravel at Borehole 4270 but appears to be more sand-rich at Borehole 17164. At Takapau-1, the Young Gravel may be less than 20 m thick based on the SkyTEM resistivity model. There is no clear boundary in the lithology logs between the Young and Salisbury Gravel, and the entire package of gravel is 50 m thick.

None of the three boreholes in this area contain a prominent ash layer equivalent to the Potaka Ignimbrite, observed in Borehole 17136. However, a thick ash layer is present at Borehole 4697 (drilled to 122 m depth) that lies 4.5 km to the north of Borehole 17164. This layer could be the Potaka Ignimbrite, illustrating the local variability in the deposition or re-working of the ash.

The Undifferentiated Late Pleistocene units of alternating sand, silt, clay and gravel extend from 80 m depth to 260 m depth at Borehole 4270. The SkyTEM resistivity is low (< 20 ohm.m), with a minimum of 10 ohm.m at 200 m depth corresponding to a thicker clay unit. The low resistivity layer extends to Borehole 17164 but is slightly deeper than the borehole, so its composition cannot be confirmed (Figure 4.3).

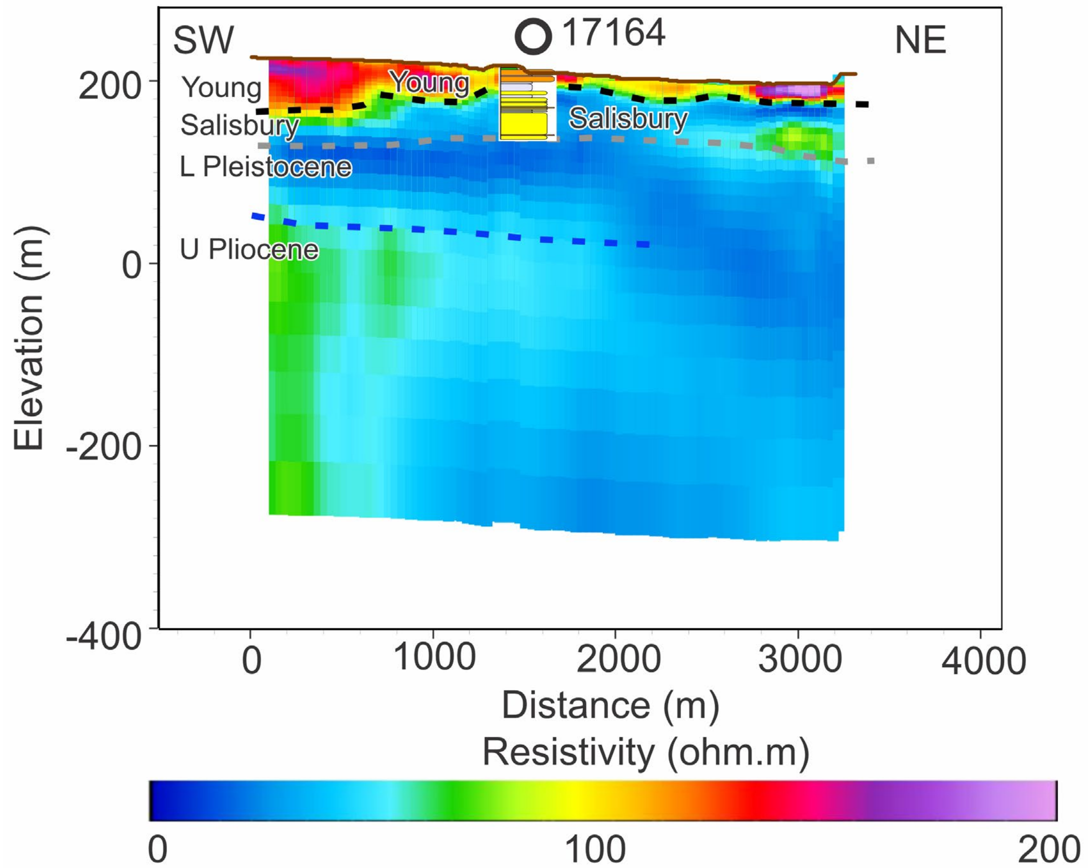


Figure 4.3 SkyTEM section through Borehole 17164 showing a thin high-resistivity surficial layer (Young Gravel) at the well. In the section illustrated, the Salisbury Gravel cannot be distinguished from the Undifferentiated Late Pleistocene in the SkyTEM models. The location is shown in Figure 4.1. Vertical scale is 5:1.

The petroleum borehole Takapau-1 lies on the crest of an anticline (Takapau thrust), and the Salisbury Gravel sits directly on clay and shell beds of the Mangaheia Group, Kumeroa Formation (Leslie 1971b). The resistivity logs in the borehole confirm an increase to greater than 100 ohm.m in the limestones (Mangaheia Group, Te Onepu Formation) at 200 m depth (Francis 2001). Boreholes 17164 and 4270 lie in the syncline to the east of the Takapau thrust and the higher resistivity layers are significantly deeper in the SkyTEM sections (> 300 m). The seismic data close to Borehole 17164 indicates that the strata at 200–400 m depth are consolidated and well bedded, so the lower resistivity may indicate a higher mudstone content in the Upper Pliocene section. In Figure 4.3, the base of the low-resistivity layer is interpreted to be the top of the Upper Pliocene Limestone/Mudstone.

4.2 Cross-Sections

A series of boreholes lie on a section along the eastern edge of the Ruataniwha Plains (4702 to 4450 / Speedy-1 to 4694). Boreholes 4702, 4450, Speedy-1 and 4694 were drilled to 106 m, 81 m, 877 m and 44 m depth, respectively. Borehole 4702 has a 40-m-thick layer of Young Gravel sitting on 40 m of alternating sand, organic, silt and clay layers. The basal 25 m of the borehole is dominated by siltstone and limestone. The top of the consolidated limestone units that are exposed in the hills to the east of the borehole is described as the Mangaheia Group, Pukeora Oyster Shell bed. Brown (2002) correlated these shell beds with the limestone at the base of Borehole 4702. Speedy-1 and the shallow Borehole 4450, drilled at the same location, show a similar sequence of Young Gravel, Salisbury Gravel and a thin Undifferentiated Late Pleistocene interval underlain by the consolidated Upper Pliocene sediments. The top of the Mangaheia Group (locally referred to as the Makeretu Formation; mudstone) is picked at 80 m depth, and the Te Onepu Formation limestone is picked at 120 m depth (Johnston and Langdale 2000). Both geological units are characterised by low resistivities in the SkyTEM resistivity models.

Borehole 4694 has 40 m of gravel associated with the recent Waipawa River deposits. The surface geology map (Lee et al. 2011) shows that limestone units in the adjacent hills dip under the location of the borehole and that the gravel sits directly on limestone. The resistivity model shows a contact at 125 m depth (well below the base of Borehole 4694) where the resistivity drops sharply to less than 20 ohm.m. This contact in the geophysical data may be the base of the limestone unit.

Figure 4.4 shows the regional section through Boreholes 4702, 4450/Speedy-1 and 4694. The profile is sub-parallel to geological strike, and the Undifferentiated Late Pleistocene and Upper Pliocene units vary along the section depending on the structural dip of the formations and level of erosion.

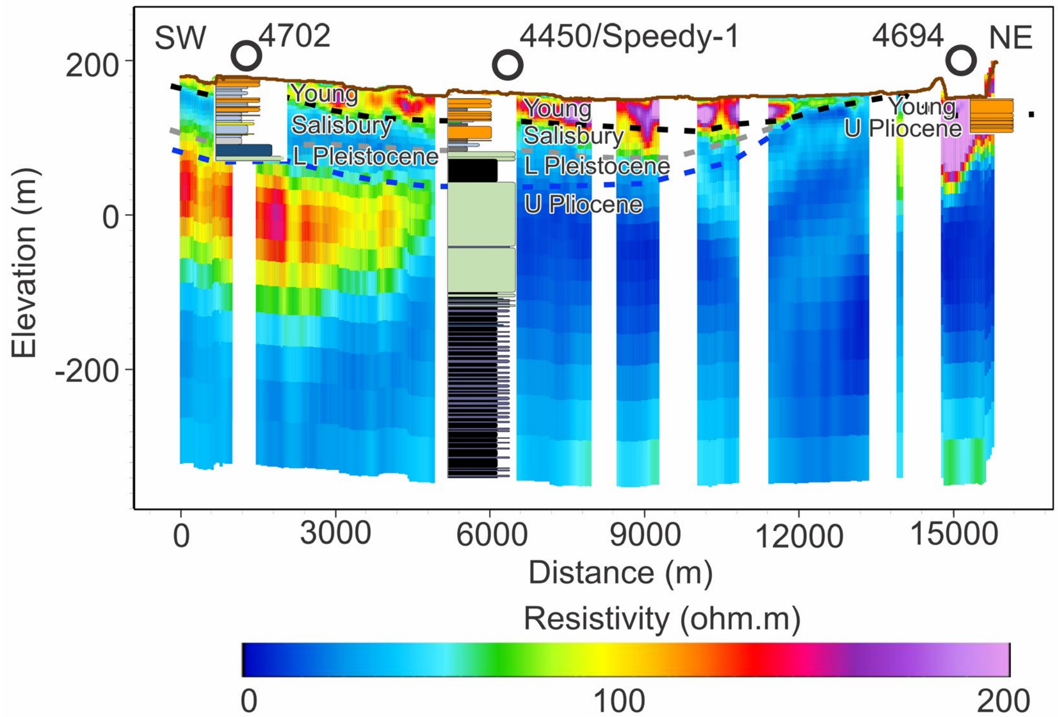


Figure 4.4 SkyTEM section through Boreholes 4702, 4450/Speedy-1 and 4694. The Young Gravel has high resistivity and the Salisbury Gravel has lower resistivity. The Upper Pliocene limestone units have high resistivity. The location is shown in Figure 4.1. Vertical scale is 15:1.

Two boreholes (4700 and 5425) lie in the northern part of the basin and were drilled to depths of 149 m and 156 m, respectively. Borehole 4700 has a thick Young Gravel unit over a thick lower-resistivity Salisbury Gravel that contains the Potaka Ignimbrite. The base of the Young Gravel and the base of the Salisbury Gravel are both sharp. Borehole 5425 is located further to the north. The wedge of combined Young Gravel and Salisbury Gravel is less than 50 m thick, and the Undifferentiated Late Pleistocene sediments are clearly marked as a low resistivity layer below the Salisbury Gravel. The borehole extends into consolidated sandstone at 140 m depth, and the SkyTEM resistivity increases to 75 ohm.m. The intermediate resistivity layer is 40 m thick and continues to the north, where it is within 40 m of the ground surface.

Borehole 5425 is shown on a SkyTEM section that illustrates the shallowing of the units towards the northeast (Figure 4.5).

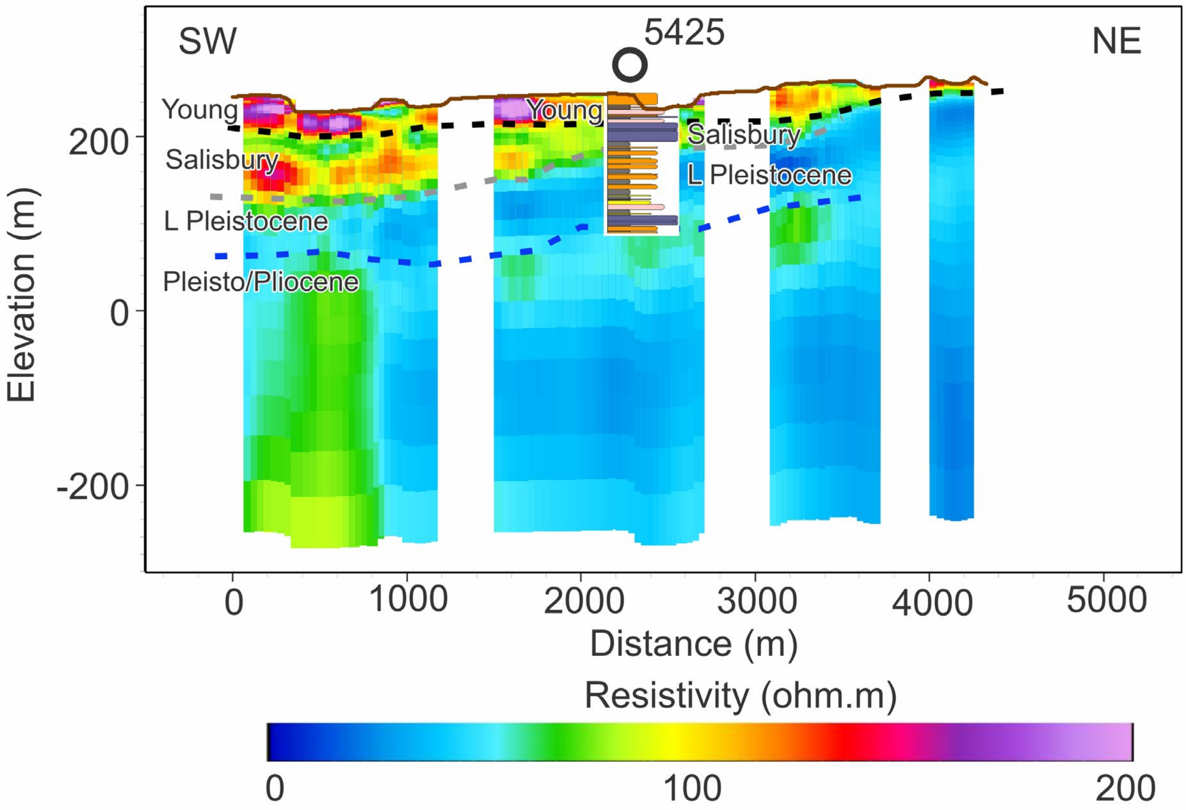


Figure 4.5 SkyTEM section through Borehole 5425. The Young Gravel has high resistivity and the Salisbury Gravel has lower resistivity. The location is shown in Figure 4.1. Vertical scale is 5:1.

4.3 Hydrogeological Basement

As part of the interpretation of the SkyTEM data and construction of a detailed hydrogeological model, an important boundary that needs to be defined is the top of the hydrogeological basement. Following the details described within Tschritter et al. (2022), the hydrogeological basement was defined as all pre-Quaternary deposits, primarily Mangaheia Group (Pliocene limestone, sandstone and siltstone, including shell beds and shelly conglomerates, deposited in a marine environment) or the older Tolaga Group (Miocene sandstone, mudstone and limestone). Sahoo et al. (2023) have used this definition to map the top of the hydrogeological basement across the entire area of the Ruataniwha SkyTEM survey. The detailed interpretation of the boreholes in this report provided controls for the interpretation undertaken by Sahoo et al. (2023).

Above the top of the hydrogeological basement, the geology is laterally heterogeneous and boundaries between units are not clear, making it difficult to map continuous geological formations. The base of the Young Gravel is the most reliable horizon identifiable in the SkyTEM resistivity model.

Based on the analysis of the detailed boreholes in this study, the top of the hydrogeological basement varies from being directly below the Young Gravel (Borehole 4694) to lying at the base of the Undifferentiated Late Pleistocene (Borehole 4631). However, for most boreholes reviewed in this study, the top of the hydrogeological basement is picked at the base of the Salisbury Gravel. The resistivity contrast at the contact is mostly a change from high resistivity to low resistivity with increasing depth. However, in some places, the resistivity increases or does not change. Additional geological constraints are needed to identify the boundary in these areas.

5.0 SUPPLEMENTAL MATERIAL

The composite logs for the 15 boreholes used in this study are attached as a PDF file at a vertical scale of 1:2000.

Yours sincerely,

Richard Kellett Senior Geoscientist	Zara Rawlinson Senior Hydro-Geophysicist	Maïwenn Herpe Hydrogeologist

6.0 ACKNOWLEDGEMENTS

This work has been jointly funded by the New Zealand Government's Provincial Growth Fund, Hawke's Bay Regional Council and GNS Science's Strategic Science Investment Fund (Ministry of Business, Innovation & Employment). The report has benefited from discussions with Tusar Sahoo, Angela Griffin, Julie Lee, Conny Tschritter and Simon Harper (Hawke's Bay Regional Council). We thank Malcolm Arnot for providing report reviews.

7.0 REFERENCES

Brown LJ. 2002. Ruataniwha Plains groundwater exploration borehole results. Mountain Creek (AU): LJ Brown. 21 p. + appendices. Prepared for Hawkes Bay Regional Council.

Francis D. 2001. Subsurface geology of the Ruataniwha Plains and relation to hydrology. Lower Hutt (NZ): Geological Research Ltd. 28 p. Technical Report. Prepared for Hawke's Bay Regional Council.

Johnston J, Langdale S. 2000. Speedy-1/1A well completion report. PEP 38332. Located at: Ministry of Business, Innovation & Employment, Wellington, NZ. 356 p. + 1 enclosure. New Zealand Unpublished Petroleum Report 2537.

Lawrence MJF, Herpe M, Kellett RL, Pradel GJ, Sanders F, Coup L, Rawlinson ZJ, Reeves RR, Brakenrig T, Cameron SG, et al. 2022a. Hawke's Bay 3D Aquifer Mapping Project: drilling completion report for borehole 17136 (3DAMP_Well1), Ongaonga–Waipukurau Road, Ruataniwha Plains. Lower Hutt (NZ): GNS Science. 156 p. Consultancy Report 2022/31. Prepared for Hawke's Bay Regional Council.

Lawrence MJF, Herpe M, Pradel GJ, Kellett RL, Coup L, Sanders F, Rawlinson ZJ, Reeves RR, Brakenrig T, Cameron SG, et al. 2022. Hawke's Bay 3D Aquifer Mapping Project: drilling completion report for borehole 17164 (3DAMP_Well3), Burnside Road, Ruataniwha Plains. Lower Hutt (NZ): GNS Science. 76 p. Consultancy Report 2022/15. Prepared for Hawke's Bay Regional Council.

Lee JM, Bland KJ, Townsend DB, Kamp PJJ, compilers. 2011. Geology of the Hawke's Bay area [map]. Lower Hutt (NZ): GNS Science. 1 folded map + 93 p., scale 1:250,000. (Institute of Geological & Nuclear Sciences 1:250,000 geological map; 8).

Leslie WC. 1971a. Ongaonga-1. Located at: Ministry of Business, Innovation & Employment, Wellington, NZ. 95 p. + 2 enclosures. New Zealand Unpublished Petroleum Report 271.

Leslie WC. 1971b. Takapau-1. Located at: Ministry of Business, Innovation & Employment, Wellington, NZ. 84 p. + 1 enclosure. New Zealand Unpublished Petroleum Report 273.

Rawlinson ZJ, Reeves RR, Westerhoff RS, Foged N, Pederson JB, Kellett RL. 2022. Hawke's Bay 3D Aquifer Mapping Project: Ruataniwha Plains SkyTEM data processing and resistivity models. Wairakei (NZ): GNS Science. 79 p. Consultancy Report 2022/38. Prepared for Hawke's Bay Regional Council.

Sahoo TR, Rawlinson ZJ, Kellett RL. 2023. Hawke's Bay 3D Aquifer Mapping Project: delineation of hydrogeological basement within the Ruataniwha Plains from SkyTEM-derived resistivity models. Lower Hutt (NZ): GNS Science. 10 p. Consultancy Report 2023/39LR. Prepared for Hawke's Bay Regional Council.

Tschritter C, Herpe M, Kellett RL, Rawlinson ZJ, Arnot MJ, Griffin AG, Lawrence MJF. 2022. Hawke's Bay 3D Aquifer Mapping Project: Ruataniwha Plains data and model inventory. Wairakei (NZ): GNS Science. 111 p. Consultancy Report 2022/76. Prepared for Hawke's Bay Regional Council.

APPENDIX 1 SUPPLEMENTAL DATA

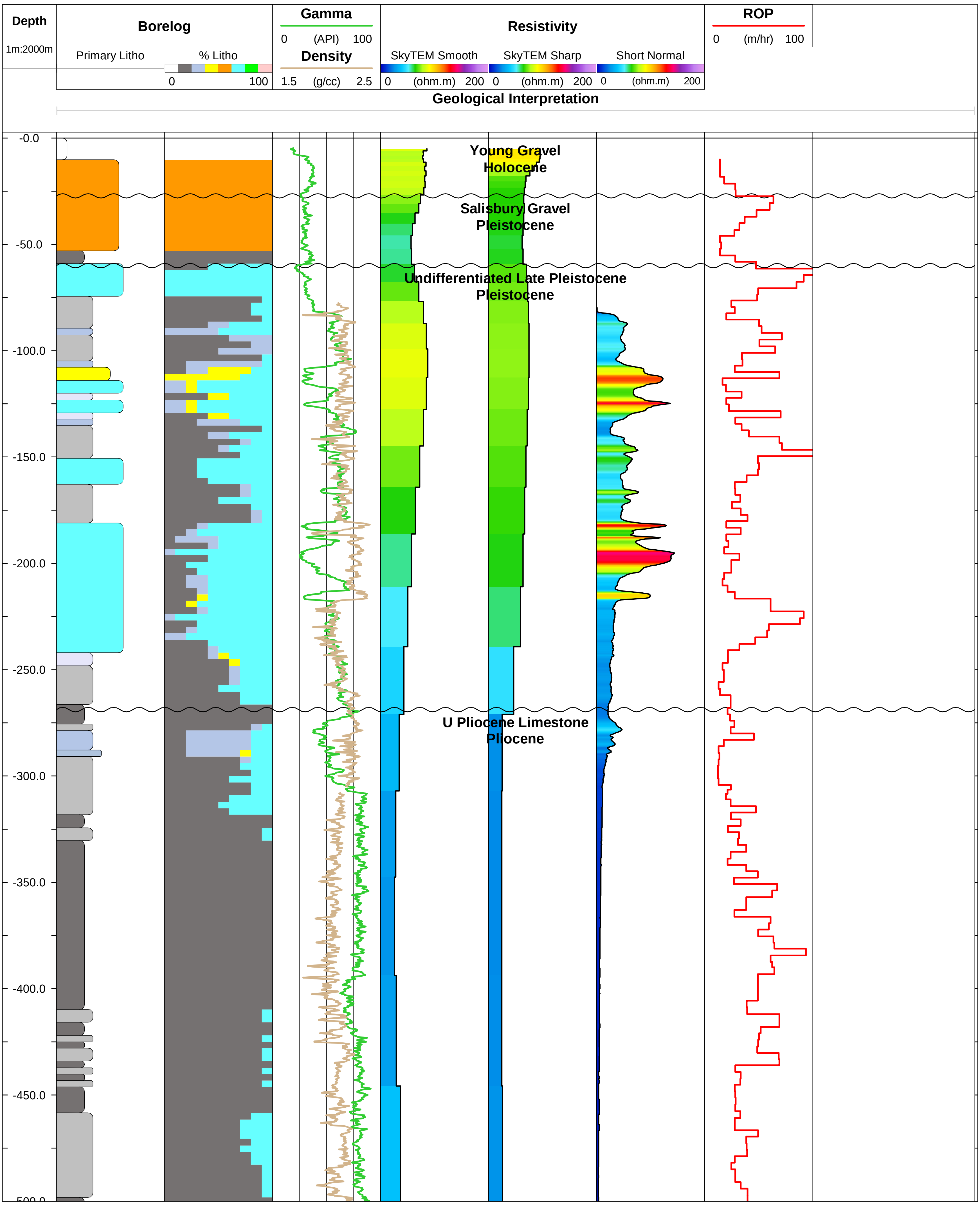
PROJECT:	HBRC 3D-AMP Ruataniwha Basin
BOREHOLE:	Takapau-1
LOCATION (NZTM):	1 883 144 m E; 5 569 235 m N
ELEVATION:	GL 262.7 amsl DF 267.6 amsl
LOGGER:	Compiled by RL Kellett
DATE:	28 April 2023

REMARKS:

Depths are referenced to the Drilling Floor (DF).
Shallow logs have been digitised from the composite log.
The surface casing extends to 80 m depth.
Rate of Penetration (ROP) is from the drilling report.
The drilling report contains a table of stratigraphic tops.
Upper Pliocene : Top Nukumaruan (Wn) at 52 m
Mid Pliocene : Top Mangapanian (Wm) at 228 m

Clay Silt Sand Gravel Shells Organic Tephra

Lithology

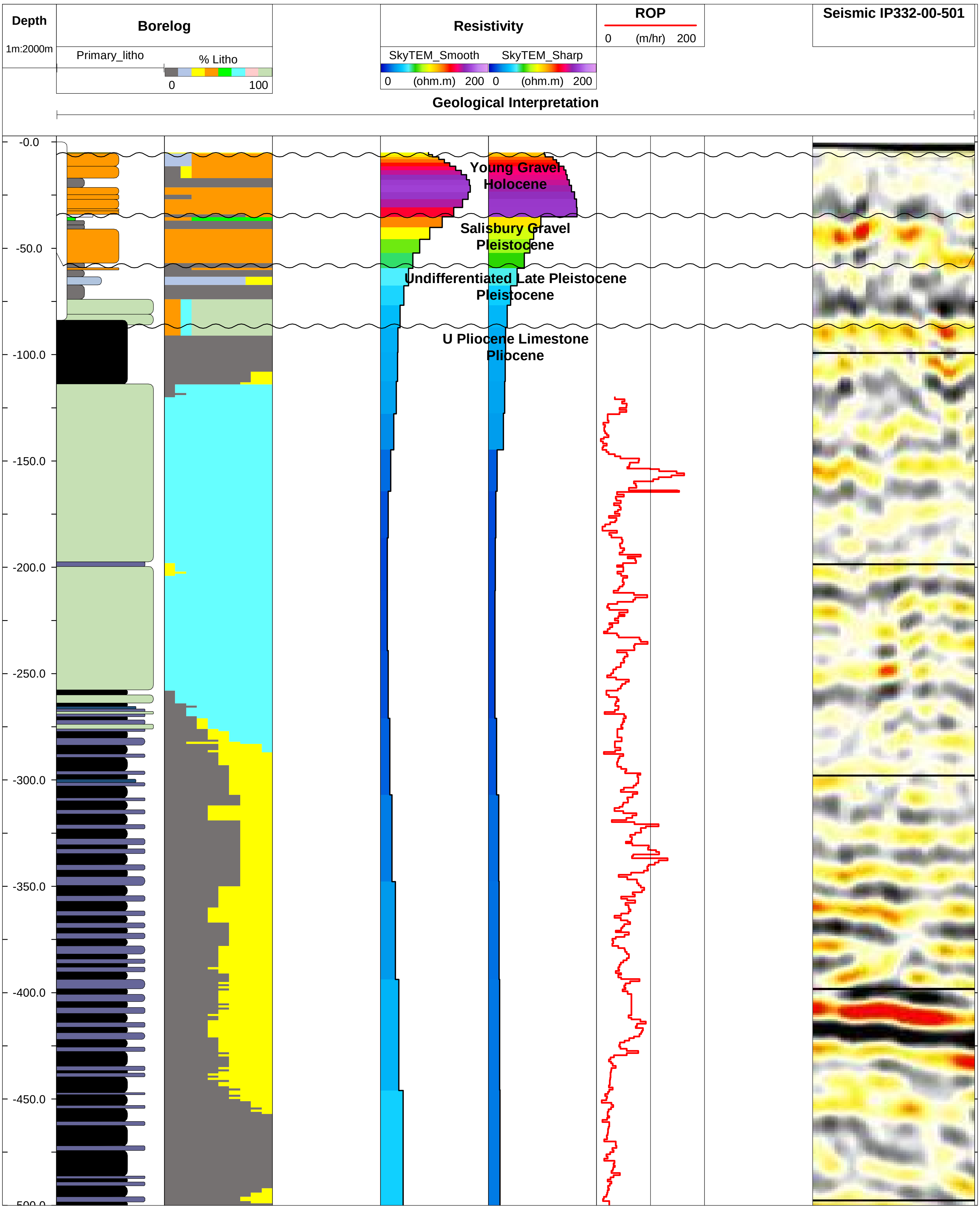


PROJECT:	HBRC 3D-AMP Ruataniwha Basin
BOREHOLE:	Speedy-1 and 4450
LOCATION (NZTM):	1 895 580 m E; 5 568 257 m N
ELEVATION:	GL 160 amsl DF 165 amsl
LOGGER:	Compiled by RL Kellett
DATE:	28 April 2023

REMARKS:

Depths are referenced to Drilling Floor (DF).
Rate of Penetration (ROP) is from the composite log.
Well 4450 is the surface hole at Speedy-1.
Seismic line IP332-00-501 intersects the well.
No logs were collected in Speedy-1.
The drilling report contains a table of stratigraphic tops.
Upper Pliocene : Top Nukumaruan (Wn) at 86 m
Mid Pliocene : Top Mangapanian (Wm) at 117 m
Lower Pliocene : Top Waipipian (Wp) at 250 m

Lithology: Clay, Silt, Sand, Gravel, Shells, Organic, Tephra

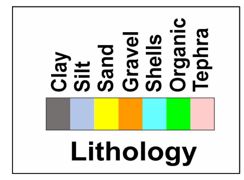


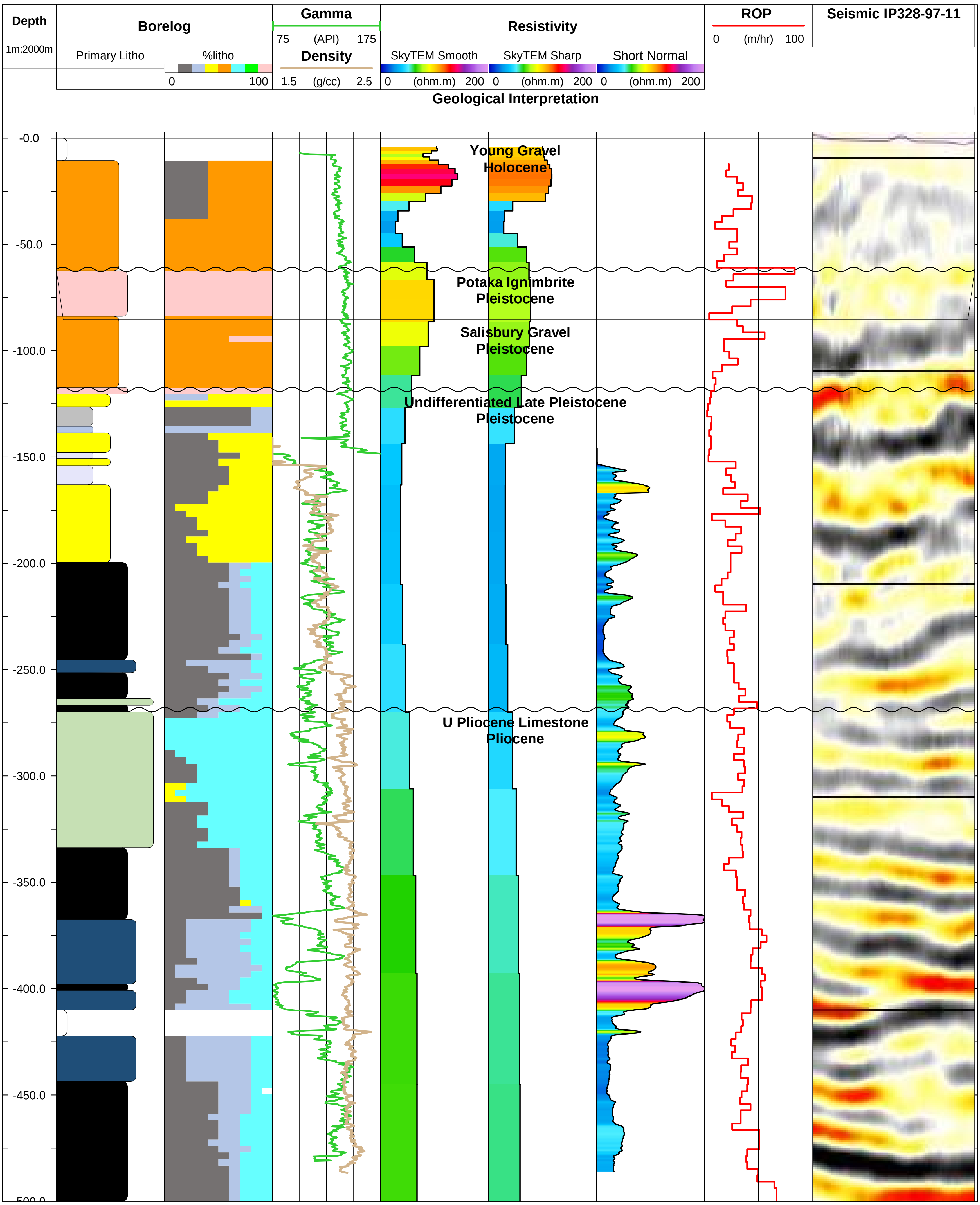
PROJECT: HBRC 3D-AMP Ruataniwha Basin

BOREHOLE: Ongaonga-1
LOCATION (NZTM): 1 891 705 m E; 5 576 880 m N
ELEVATION: GL 202.9 amsl DF 206.7 amsl
LOGGER: Compiled by RL Kellett
DATE: 28 April 2023

REMARKS:

Depths are referenced to the Drilling Floor (DF).
Rate of Penetration (ROP) is from drilling report.
The surface casing extends to 150 m.
Seismic line IP-328-97-11 passes through the well.
The drilling report contains a table of stratigraphic tops.
Pleistocene : Top Castlecliffian (Wc) at 118 m
Upper Pliocene : Top Nukumaruan (Wn) at 242 m





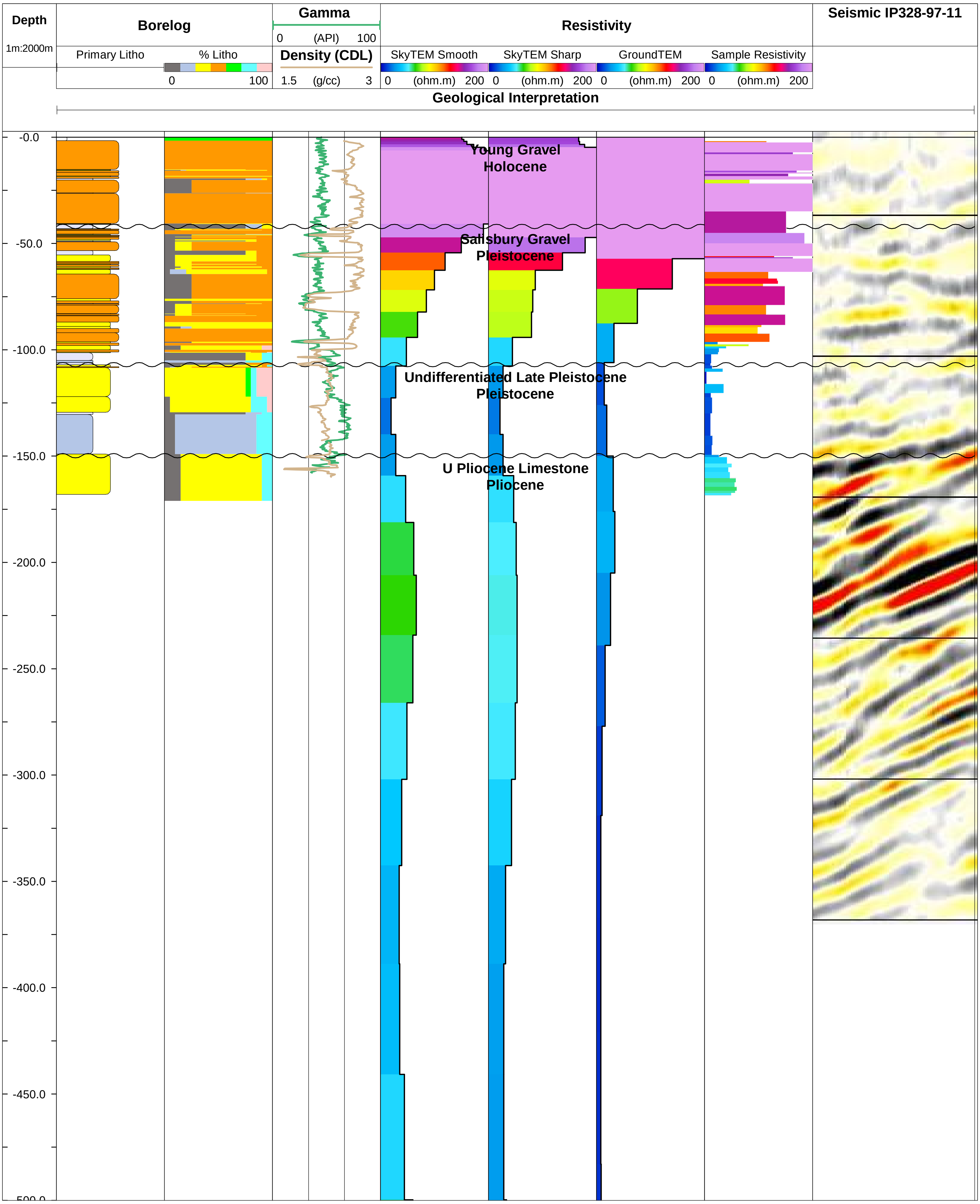
PROJECT: HBRC 3D-AMP Ruataniwha Basin

BOREHOLE: 17136 3DAMP_Well_1
LOCATION (NZTM): 1 896 508 m E; 5 572 997 m N
ELEVATION: GL 161 amsl
LOGGER: Compiled by RL Kellett
DATE: 28 April 2023

REMARKS:

Depths are referenced to ground level (GL).
Resistivity measured on saturated samples from cuttings.
Wireline logs collected through casing by RDCL.
Seismic line IP328-97-11 lies 1000 m south of the borehole.

Lithology: Clay, Silt, Sand, Gravel, Shells, Organic, Tephra



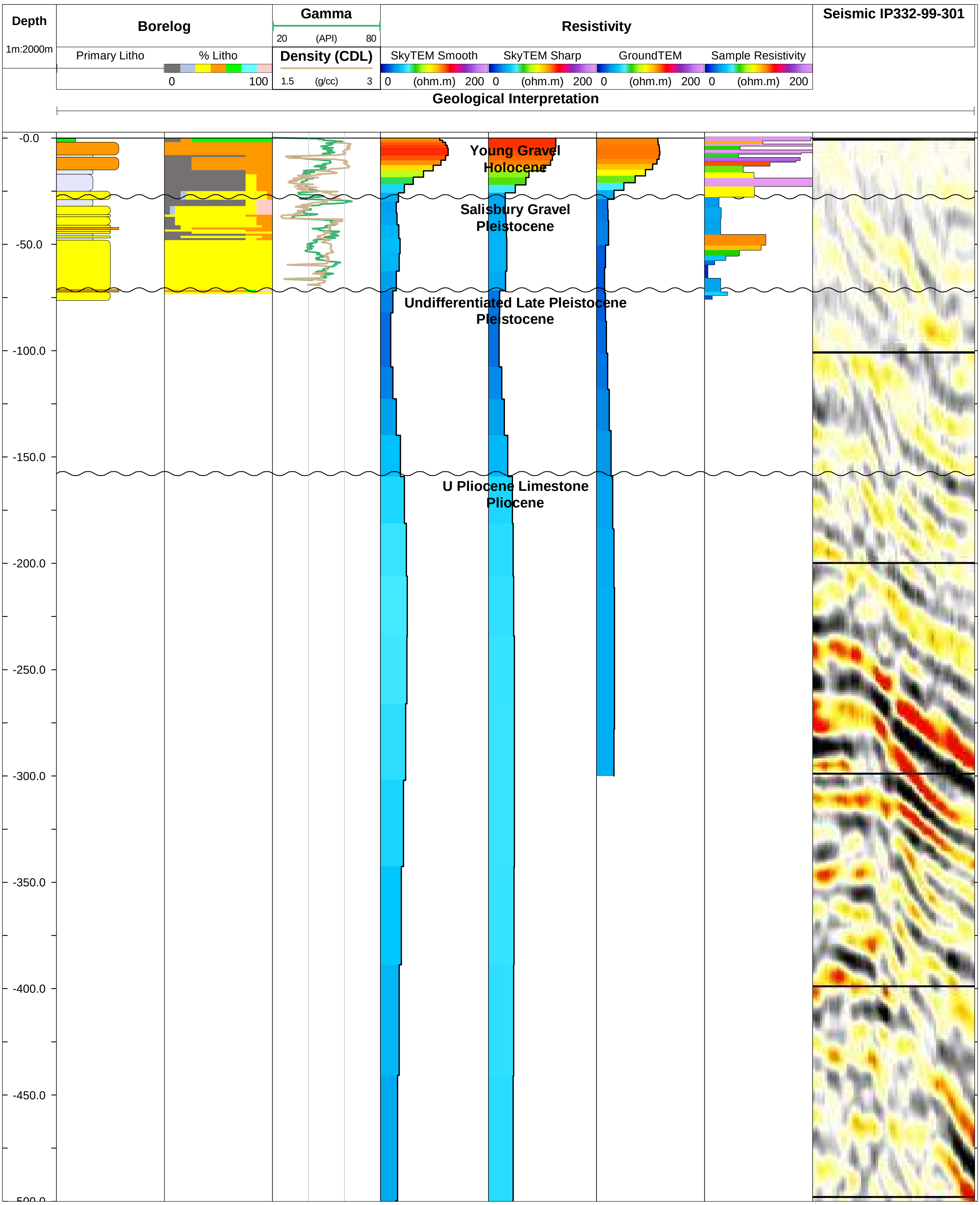
PROJECT: HBRC 3D-AMP Ruataniwha Basin

BOREHOLE: 17164 3DAMP_Well_3
LOCATION (NZTM): 1 887 255 m E; 5 567 708 m N
ELEVATION: GL 209.6 amsl
LOGGER: Compiled by RL Kellett
DATE: 28 April 2023

REMARKS:

Depths are referenced to ground level (GL).
Resistivity measured on saturated samples from cuttings.
Wireline logs collected through casing by RDCL.
Seismic line IP-332-99-301 is 800 m NE of the borehole.

Clay, Silt, Sand, Gravel, Shells, Organic, Tephra
Lithology



PROJECT: HBRC 3D-AMP : Ruataniwha Basin

BOREHOLE: 4270

LOCATION (NZTM): 1 890 450 m E; 5 568 344 m N

ELEVATION: GL 183.947 amsl

LOGGER: Compiled by RL Kellett

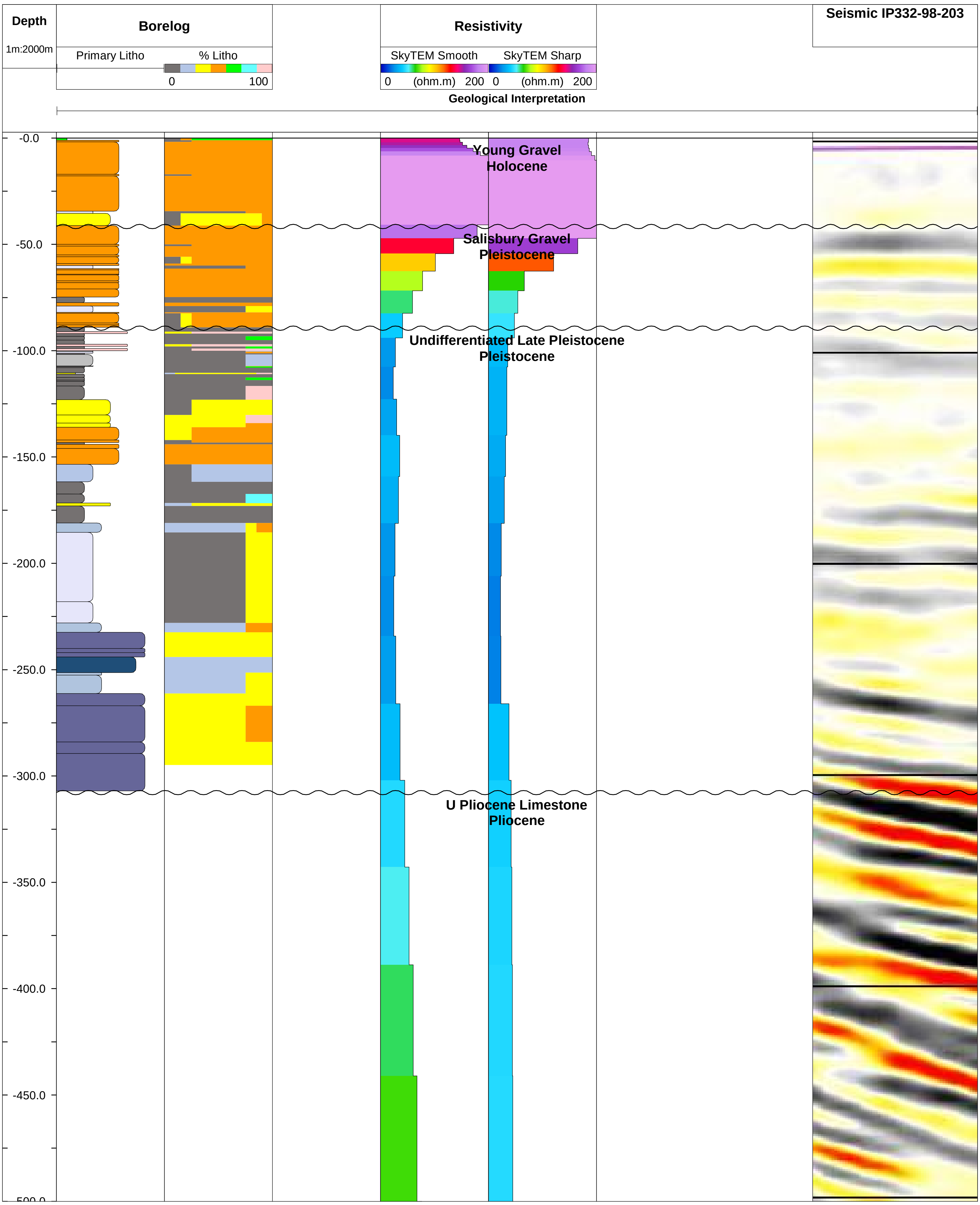
DATE: 28 April 2023

REMARKS:

Depths are referenced to ground level (GL).

Seismic Line IP332-98-203 is 100 m south of the borehole

Lithology: Clay, Silt, Sand, Gravel, Shells, Organic, Tephra

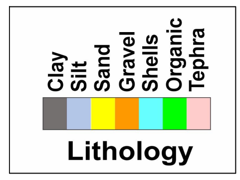


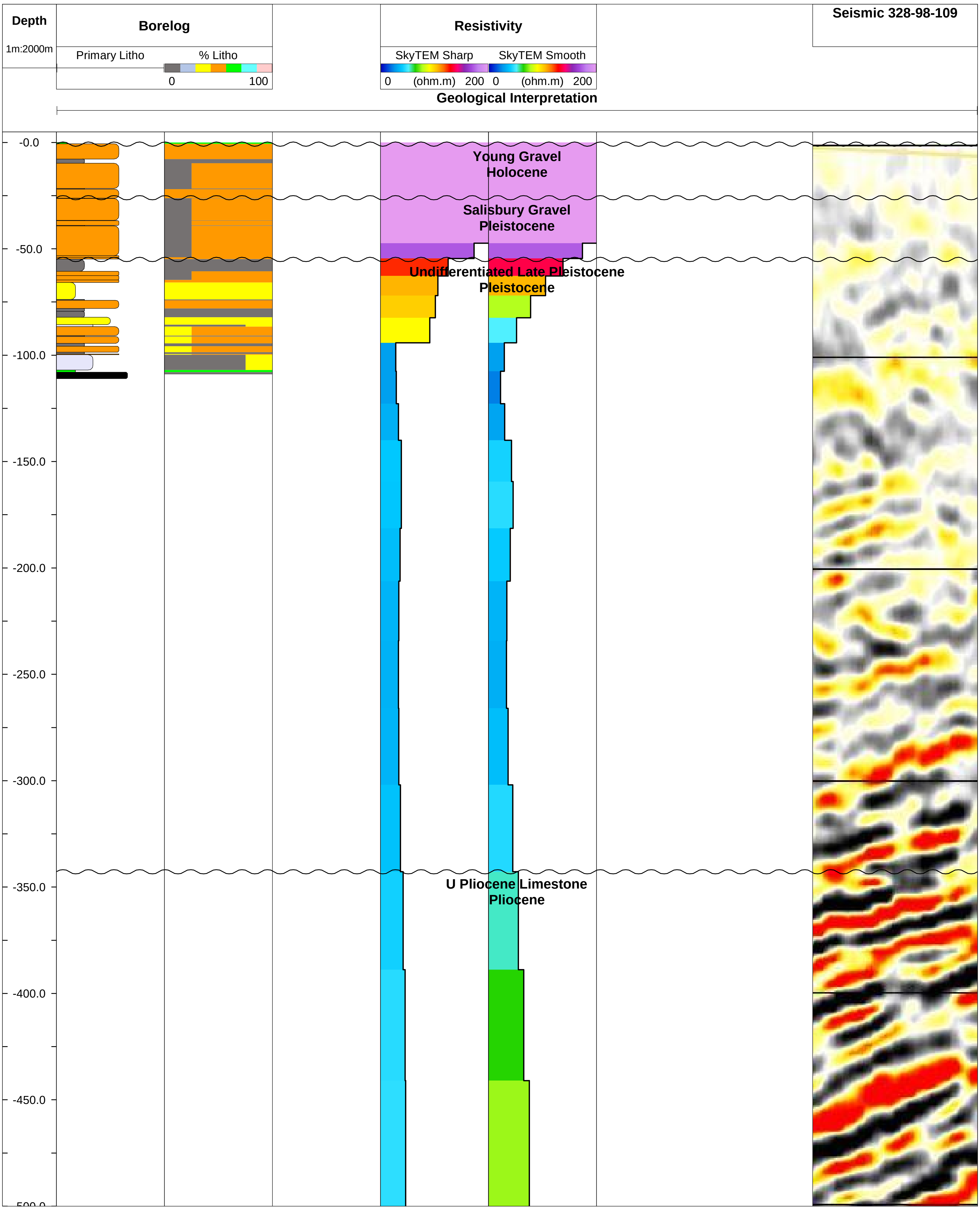
PROJECT: HBRC 3D-AMP Ruataniwha Basin

BOREHOLE: 4566
LOCATION (NZTM): 1 898 684 m E; 5 582 866 m N
ELEVATION: GL 196 amsl
LOGGER: Compiled by RL Kellett
DATE: 28 April 2023

REMARKS:

Depths are referenced to ground level (GL).
Seismic Line IP-328-98-109 lies 600 m south of the borehole.



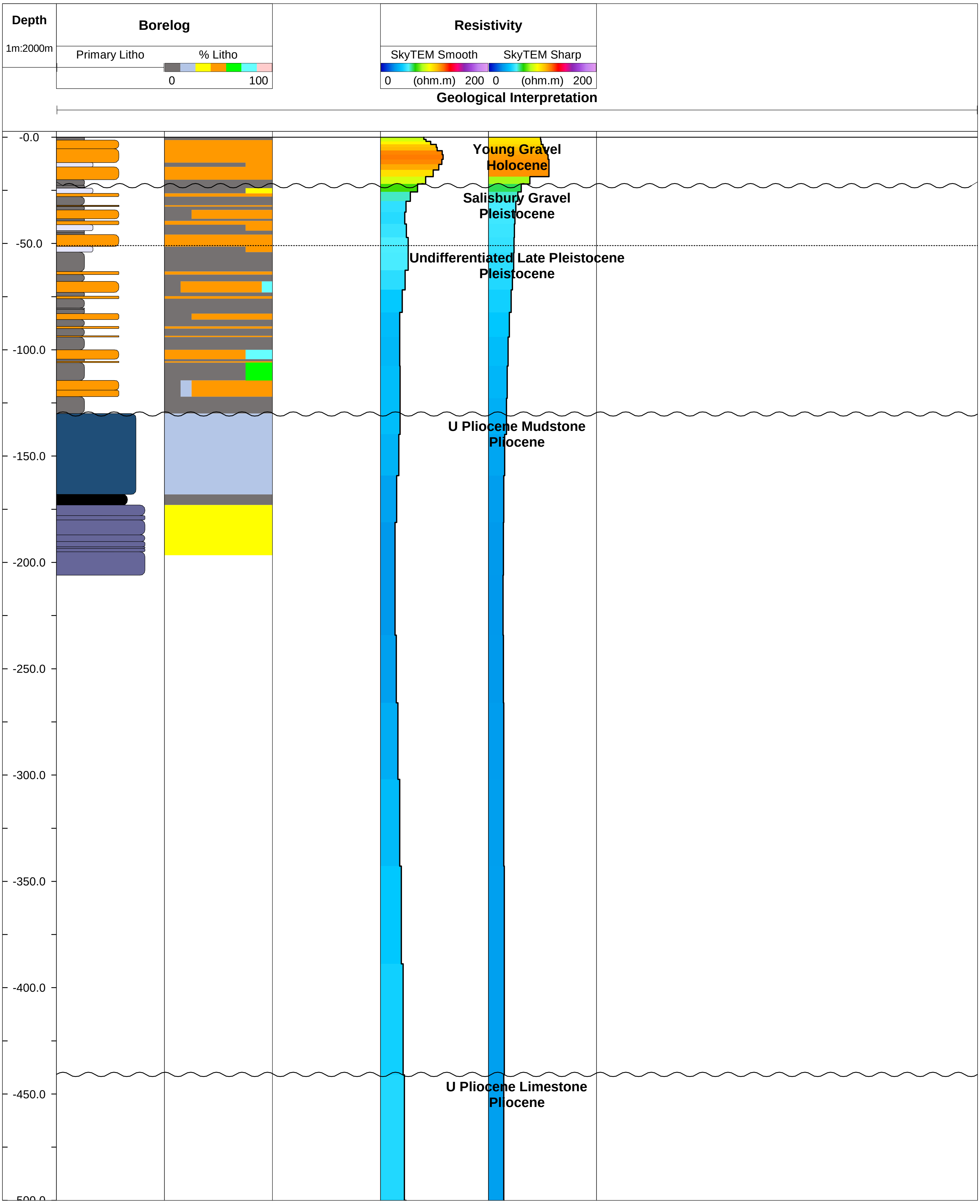


PROJECT:	HBRC 3D-AMP Ruataniwha Basin	
BOREHOLE:	4631	
LOCATION (NZTM):	1 878 233 m E; 5 572 503 m N	
ELEVATION:	GL 364.1 amsl	
LOGGER:	Compiled by RL Kellett	
DATE:	28 April 2023	

REMARKS:

Depths are referenced to ground level (GL).
Presence of Salisbury Gravel is not well constrained.
Consolidated mudstones at the base of the borehole could be the top of the Pliocene.

Lithology: Clay, Silt, Sand, Gravel, Shells, Organic, Tephra



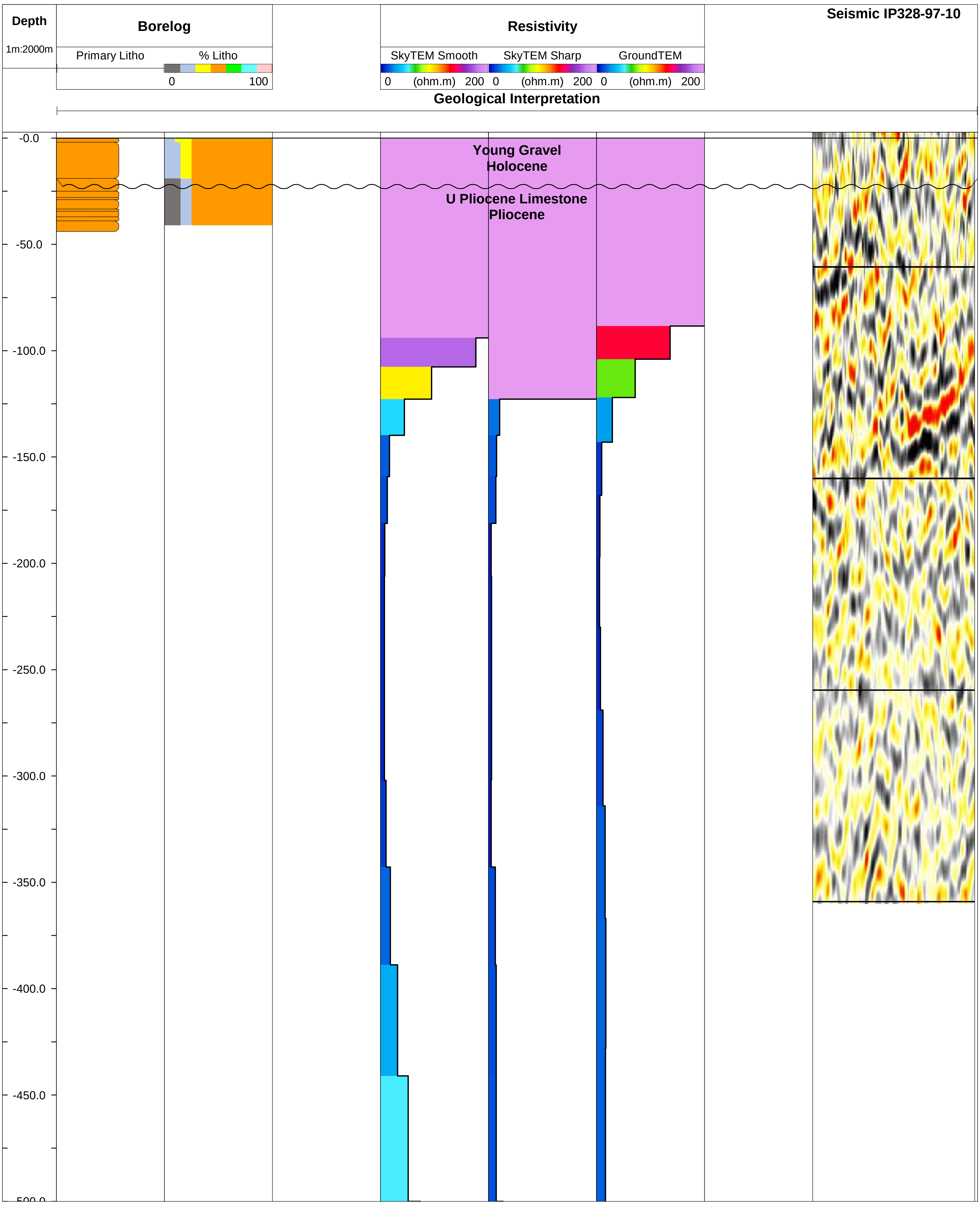
PROJECT: HBRC 3D-AMP Ruataniwha Basin

BOREHOLE: 4694
LOCATION (NZTM): 1 901 329 m E; 5 574 786 m N
ELEVATION: GL 153.8 amsl
LOGGER: Compiled by RL Kellett
DATE: 28 April 2023

REMARKS:

Depths are referenced to ground level (GL).
Seismic line IP328-97-10 is 1200 m north of the borehole.
The borehole is located in the Waipawa river with limestone outcrops to the north and south.

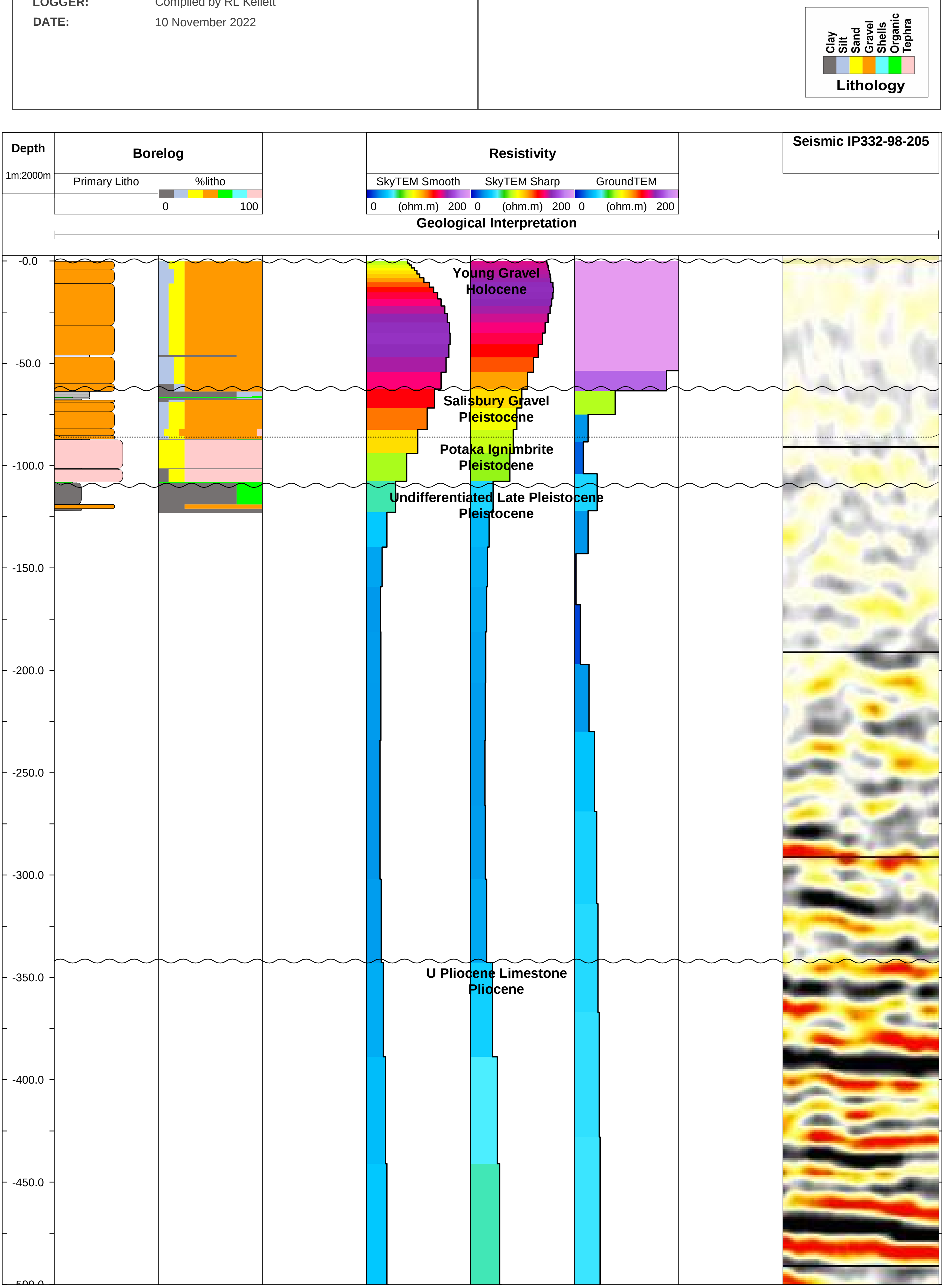
Clay Silt Sand Gravel Shells Organic Tephra
Lithology



PROJECT:	HBRC 3D-AMP Ruataniwha Basin
BOREHOLE:	4697
LOCATION (NZTM):	1 890 296 m E; 5 571 107 m N
ELEVATION:	GL 201.1 amsl
LOGGER:	Compiled by RL Kellett
DATE:	10 November 2022

REMARKS:

Depths are referenced to ground level (GL).
Line IP332-98-205 is 500 m SE of the borehole.



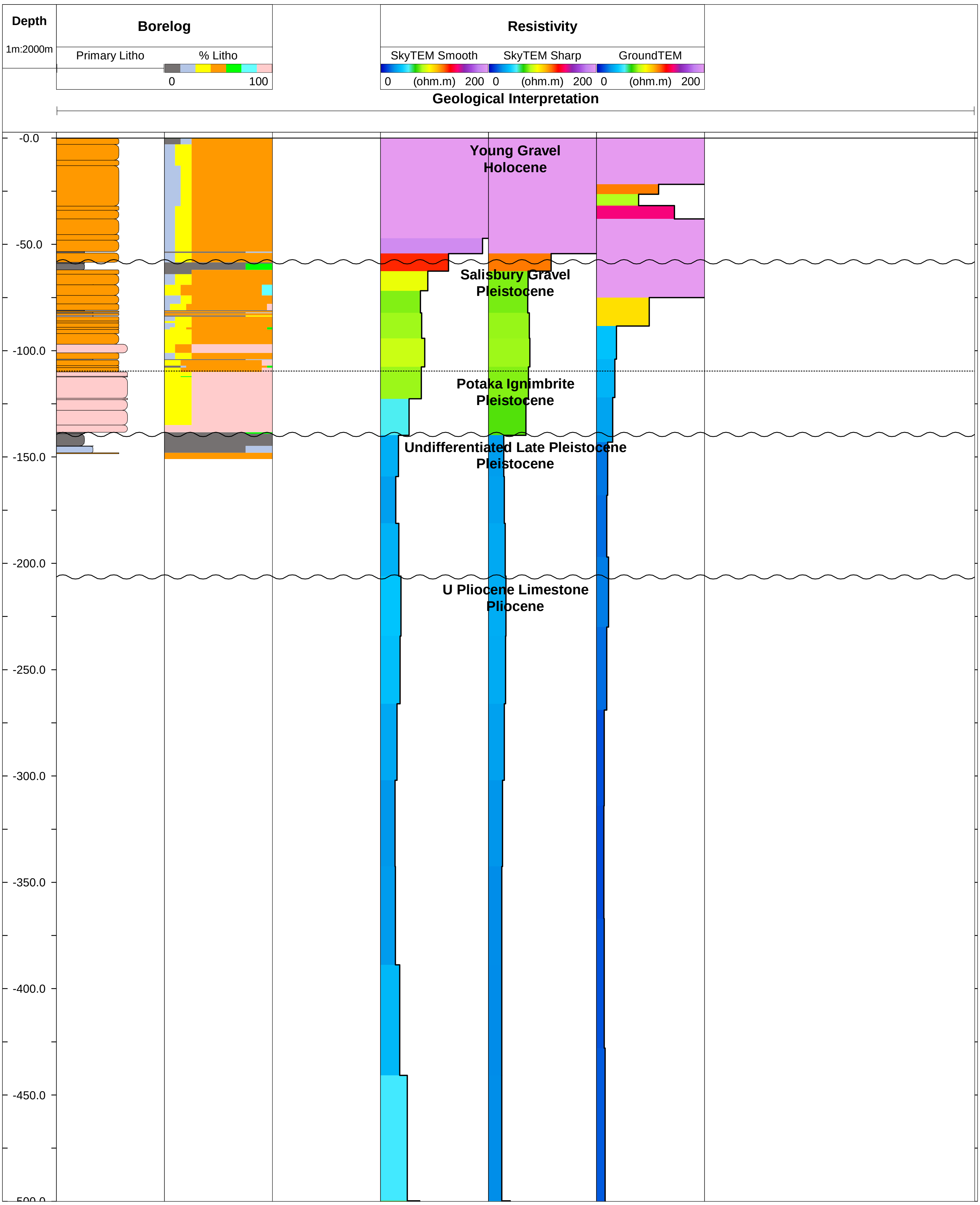
PROJECT: HBRC 3D-AMP Ruataniwha Basin

BOREHOLE: 4700
LOCATION (NZTM): 1 894 523 m E; 5 581 470 m N
ELEVATION: GL 217.9 amsl
LOGGER: Compiled by RL Kellett
DATE: 28 April 2023

REMARKS:

Depths are referenced to ground level (GL).
Brown Well 3
GroundTEM (NTEM and TEM) from 2009 survey

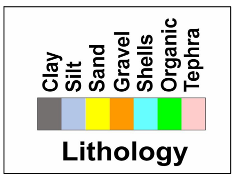
Clay | Silt | Sand | Gravel | Shells | Organic | Tephra
Lithology

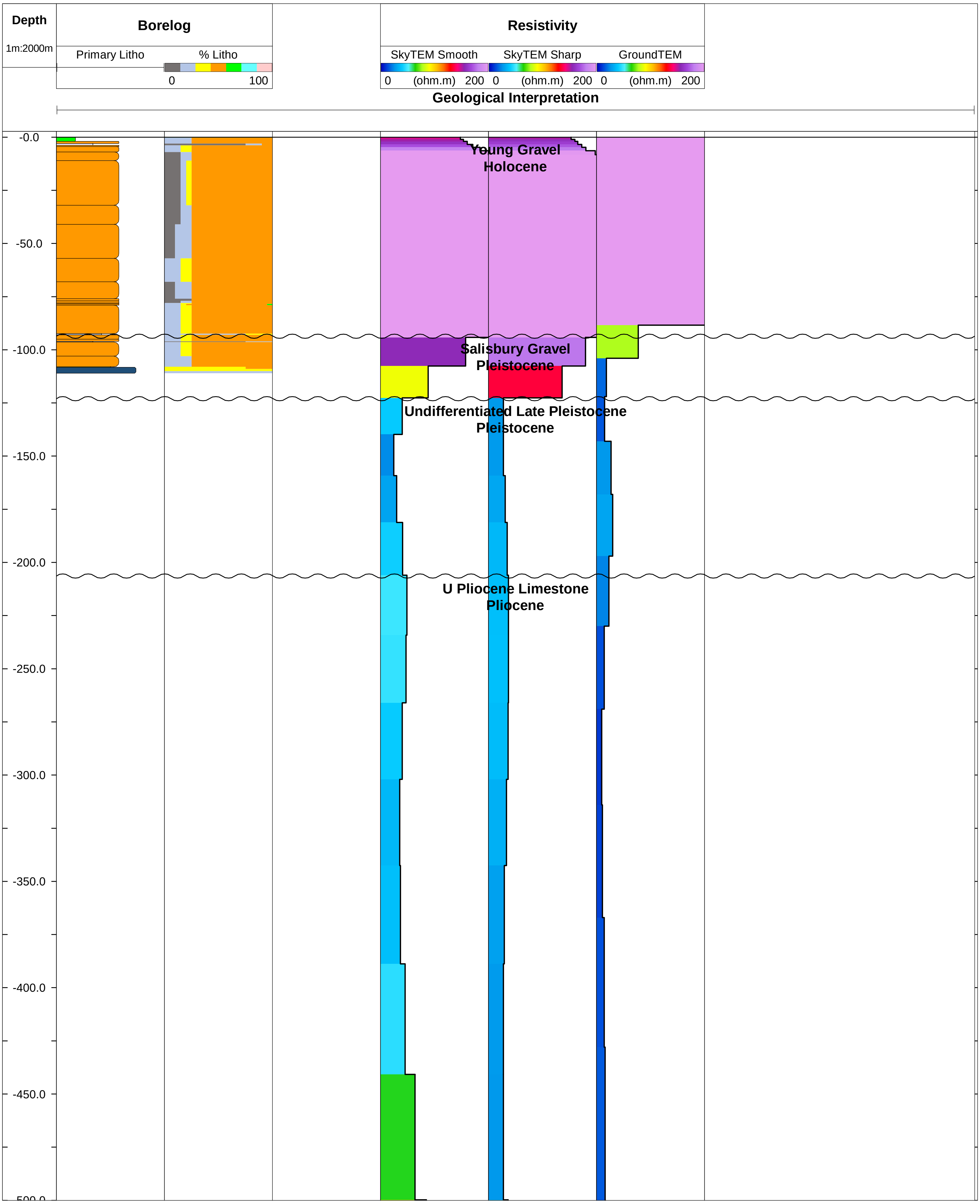


PROJECT:	HBRC 3D-AMP Ruataniwha Basin
BOREHOLE:	4701
LOCATION (NZTM):	1 897 911 m E; 5 576 587 m N
ELEVATION:	GL 174.3 amsl
LOGGER:	Compiled by RL Kellett
DATE:	28 April 2023

REMARKS:

Depths are referenced to ground level (GL).
Brown Well 4
GroundTEM (TEM) from 2009 survey





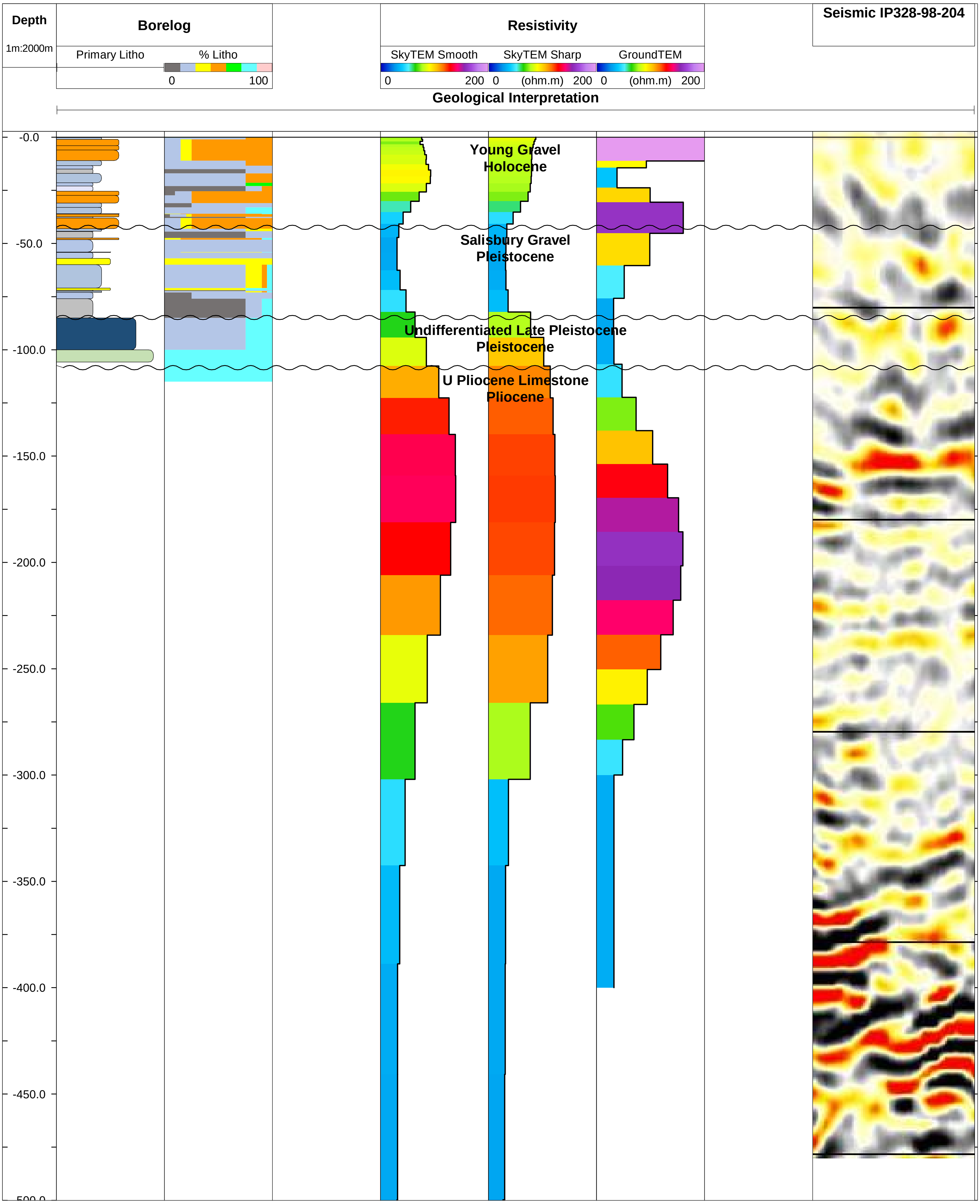
PROJECT: HBRC 3D-AMP Ruataniwha Basin

BOREHOLE: 4702
LOCATION (NZTM): 1 892 928 m E; 5 563 969 m N
ELEVATION: GL 179.2 amsl
LOGGER: Compiled by RL Kellett
DATE: 28 April 2023

REMARKS:

Depths are referenced to ground level (GL).
Brown Well 5
GroundTEM (TEM) from 2009 survey
Seismic Line IP332-98-204 intersects the borehole

Lithology: Clay, Silt, Sand, Gravel, Shells, Organic, Tephra

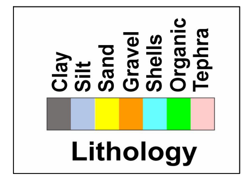


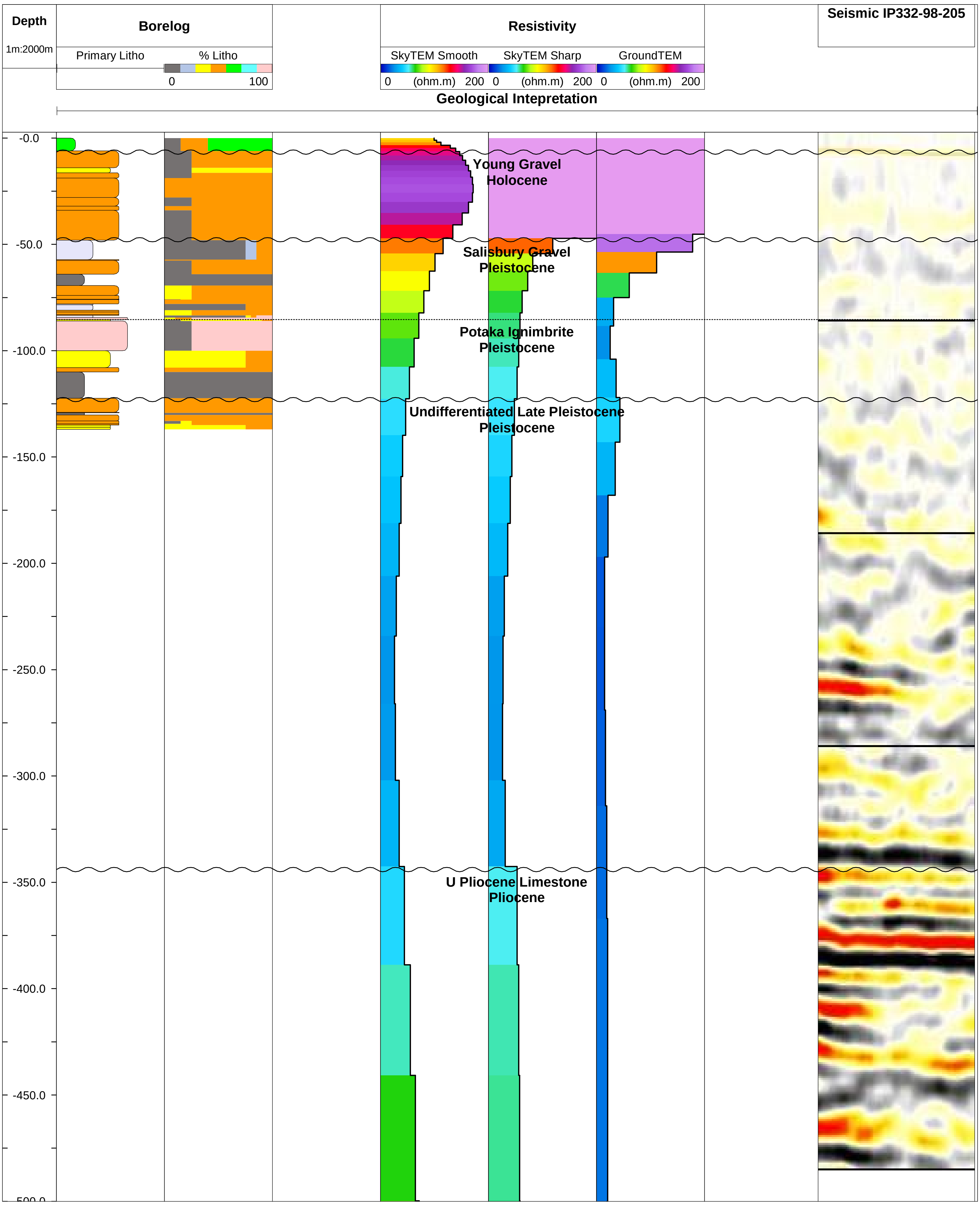
PROJECT: HBRC 3D-AMP Ruataniwha Basin

BOREHOLE: 4830
LOCATION (NZTM): 1 894 084 m E; 5 576 273 m N
ELEVATION: GL 186.7 amsl
LOGGER: Compiled by RL Kellett
DATE: 28 April 2023

REMARKS:

Depths are referenced to ground level (GL).
GroundTEM from 2009 survey.
Seismic line IP332-98-205 is 500 m east of the borehole





PROJECT: HBRC 3D-AMP Ruataniwha

BOREHOLE: 5425
LOCATION (NZTM): 1 897 691 m E; 5 590 212 m N
ELEVATION: GL 238.4 amsl
LOGGER: Compiled by RL Kellett
DATE: 28 April 2023

REMARKS:

Depths are referenced to ground level (GL).