

Yukon Geological Survey Miscellaneous Report 16

Pressure data assessment, Liard Basin, Yukon

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Cover photo: Upper Palaeozoic shales in northwest Liard Basin, Yukon.

FOREWORD

In April 2016, Yukon Geological Survey (YGS) was approached by Ikon Science Canada (Ikon) with respect to technical services they could offer to help YGS better understand the petroleum prospectivity of Liard Basin following the release of the basin's unconventional resource assessment by the National Energy Board in March of that year. Specifically, Ikon offered to conduct a preliminary scoping study of shale gas play data from Yukon's portion of Liard Basin to determine any potential for future assessment of pore pressure variability in the basin to be undertaken or contracted out by YGS at a later date. The study was a desk-top synthesis of existing, publicly-available geological and petrophysical data; no new data were collected as part of this project. The study was conducted at no charge by Ikon, with agreement that the results and recommendations could be published by YGS in the public domain.

Ikon is an independent consultancy with expertise in unconventional pressure variability assessment projects both in Canada and across the globe. The results of this scoping study, and of any future detailed pore pressure assessment in the basin, will benefit future exploration and drilling activities, in addition to identifying critical knowledge gaps to inform future research opportunities for the Yukon Geological Survey.

Carolyn Relf

Director, Yukon Geological Survey



Project Title:

Pressure Data Assessment

Geographic Location:

Liard Basin, Yukon

Type of Project:

Data Review

TECHNICAL REPORT

FOR	SUBMISSION FROM	IKON SCIENCE REFERENCE
Yukon Geological Survey	Ikon Science Canada	A-P-1605-11086-P

Written by:	Dr. Sam Green Geopressure Technical Lead (EAME)	Completed:	23 Jun 2016
Approved by:	Stephen Jenkins Senior Vice-President Geopressure	Completed:	23 Jun 2016

Version: 2.0



DISCLAIMER

The interpretations and models generated in this report represent the best technical effort by Ikon GeoPressure staff based on available data and Ikon GeoPressure's experience of pore pressure and fracture pressure analysis. Ikon GeoPressure takes no responsibility for utilisation of the data, interpretations or recommendations in this study in development of a well plan, nor in application of that well plan in the drilling of a well, nor in its use in combination with other information and data. All risk and costs associated with application of the data, results and recommendations of this study are specifically the responsibility of Yukon Geological Survey (YGS) and any other parties utilising the study, and specifically not attributable to Ikon GeoPressure or Ikon GeoPressure staff.

CHANGES RECORD

Rev No.	Comments	Date	Issued by
1.0	Initial report summarising the findings from the data assessment study	16 Jun 2016	Sam Green
2.0	Re-issued report following feedback and clarifications from YGS	23 Jun 2016	Sam Green

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1 EXECUTIVE SUMMARY

A pore pressure report synthesising the well reports, drilling histories and other written material using the current dataset could be constructed using the dataset as is currently available. The report would outline the overall pore pressure characteristics in the Yukon portion of the Liard Basin providing a valuable description for future exploration and drilling. The report would combine quantitative and qualitative descriptions of the pore pressure, with the level of interpretation dependent on the calibration data available to each well.

The current dataset is not sufficient to allow a detailed regional pore pressure study to be undertaken across all the wells as less than half the wells have detailed drilling histories; these descriptions are important in unconventional onshore plays as they provide important calibration data when estimating pore pressure in non-reservoir sections. Quantitative wireline interpretation of those wells with detailed drilling histories can be undertaken and qualitative wireline interpretations of wells without detailed drilling histories could be included with the interpretation based on log character and general trends.

Of positive note are the following;

- Nine wells contain direct pore pressure measurements that can be used to calibrate a pore pressure model.
- Four wells contain Kick data that can be used to calibrate a pore pressure model.
- There are well reports for twelve wells that provide useful information. Some reports also contain specific discussion of pore pressure indicators within the wells.
- The geological history of the area is well documented and supported with many maps and detailed written reports.
- Well reports indicate the more wireline data was acquired for some wells than is currently available and the project would benefit from this data being sourced (see the well summaries in Section 4).
- A consistent reinterpretation of the stratigraphic tops across all the wells are present that can be picked based on wireline log character.
- Despite an overall lack of density log data, the data that are present form a consistent depth trend that provides confidence that an overburden model derived from these data can be applied to those wells without data. It should be possible to build a sonic-to-density transform to generate the missing data using rock physics relationships such as Gardner et al. (1974).
- Sonic velocity data, which is the primary log for predicting pore pressure, are present in twelve wells over most depths.
- Resistivity data are also present with good vertical coverage in ten wells that could also be used to estimate the pore pressure.

Of the thirteen wells supplied, the following issues are noted and the study would benefit from any additional data being sourced;

- Only four wells contain mudweight information, which is a useful calibration tool when constructing a pore pressure profile.
- The lack of daily drilling reports (only four wells have DDRs) means that the study is missing a source of vital calibration information and without this information the resolution of analysis in non-reservoir rocks will be lower.

2 AIMS AND OBJECTIVES

- Yukon Geological Survey (YGS) is interested in acquiring information on pore pressure variability in the Exshaw-Patry and Horn River shale gas plays to better assess the viability of developing its natural gas resources in Yukon’s Liard Basin.
- YGS has provided all publicly available data (as detailed below) to Ikon in order for the latter to conduct a preliminary scoping study to determine the potential (if any) for future detailed analysis of pore pressure variability in the basin.
- On completion of the study, Ikon will report its conclusions to YGS in written format, including recommendations for further analytical work or data collection to understand better the basin’s pressure regime.
- Ikon agrees that reported conclusions of the study may be made available in the public domain by YGS.

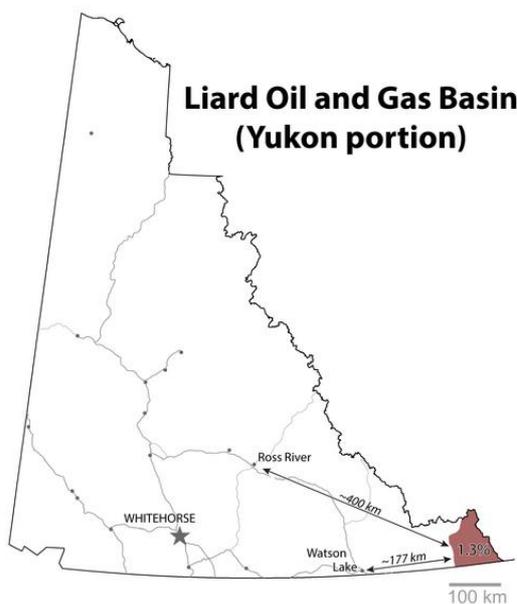
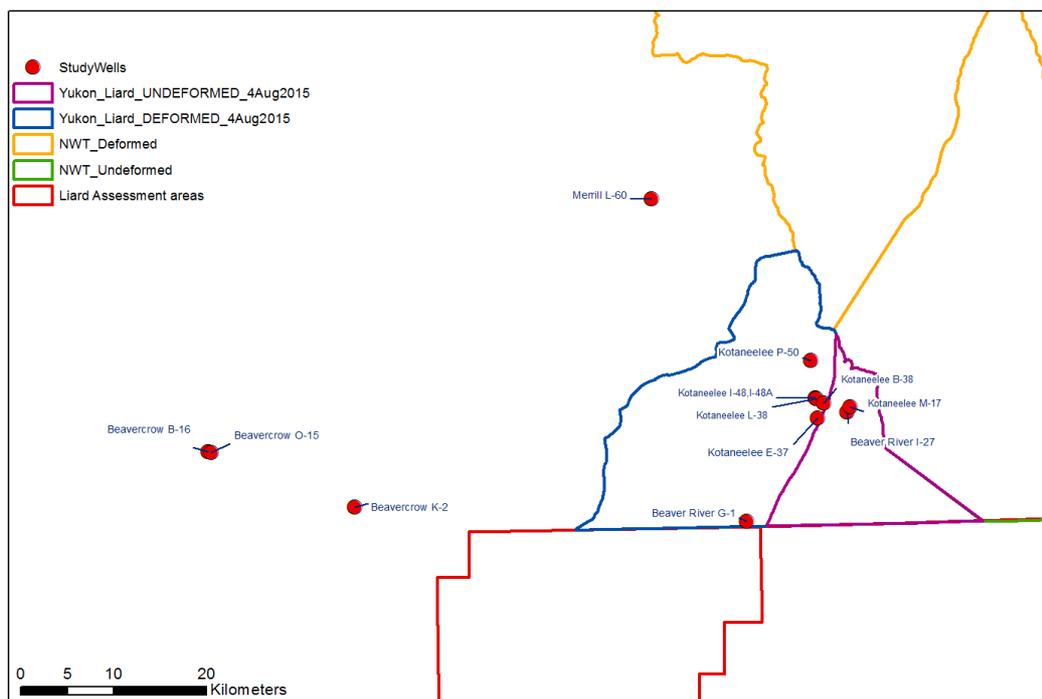


Figure 1: (Top Right) Yukon province map showing the location and extent of the Liard Basin; image courtesy of <http://www.gov.yk.ca>. (Bottom Left) Base map showing the “Assessment Areas” as supplied as GIS files by the YGS and the location of the wells in the database.



3 DATA SUMMARY

Data were supplied for 13 wells including the following;

- Geological maps
- Various reports on the regional petroleum system of Northwest Canada and the shale potential of the Liard Basin
- Fluid sample test reports
- Pressure test reports
- Temperature data
- Porosity test data and report
- Scanned wireline log data
- Well History reports
- Deviation surveys
- Composite logs
- Wireline logs

Well Name	Coordinates	Surf. Elev.	KB/RT	Deviation	Well Tops
Beaver River G-1	Y	Y	Y	Y	Y
Beaver River I-27	Y	Y	Y	Y	Y
Beavercrow B-16	Y	Y	Y	Y	Y
Beavercrow K-2	Y	Y	Y	Y	Y
Beavercrow O-15	Y	Y	Y	Y	Y
Kotaneelee B-38	Y	Y	Y	Y	Y
Kotaneelee E-37	Y	Y	Y	N	Y
Kotaneelee I-48	Y	Y	Y	Y	Y
Kotaneelee I-48A	Y	Y	Y	Y	Y
Kotaneelee L-38 & ST	Y	Y	Y	Y	Y
Kotaneelee M-17	Y	Y	Y	Y	Y
Kotaneelee P-50	Y	Y	Y	Y	Y
Merrill L-60	Y	Y	Y	Y	Y
	13	13	13	12	13

Well Name	EOWR	DDR/DMR	Lithology
Beaver River G-1	Y	N	Y
Beaver River I-27	Y	N	Y
Beavercrow B-16	Y	N	Y
Beavercrow K-2	Y	N	Y
Beavercrow O-15	Y	N	Y
Kotaneelee B-38	Y	Y	Y
Kotaneelee E-37	N	N	Y
Kotaneelee I-48	Y	Partial	Y
Kotaneelee I-48A	Y	Y	Y
Kotaneelee L-38 & ST	Y	Y	Y
Kotaneelee M-17	Y	Y	Y
Kotaneelee P-50	Y	N	Y
Merrill L-60	Y	N	Y
	12	4	13

The lithology information is a combination of cuttings descriptions and hard copy Canstrat logs supplied by the YGS that provide highly valuable information.

The following tables record the data available for each well, a written summary of each well is included in the next section and wireline data plots are shown at the end of the summaries, but the following significant notes regarding the wireline data are made below.

- The Kotaneelee L-38 is the only modern well and as such does have some drilling information recorded in the log data. The LAS data from the sidetrack files do not extend the vertical coverage of the otherwise excellent wireline data hence have not been loaded.
- Kotaneelee I-48 has separate scanned files hence its own entry in the table but no wireline data for the sidetrack are present. If the wireline data in the sidetrack are not acquired for the study or do not add vertical coverage to the main hole then the sidetrack reports will be used as ancillary data for the main hole only.

All depths are in mMD to the closest 100m						
Well Name	Gamma	Sonic	Density	Neutron	Resistivity	Caliper
Beaver River G-1	400-4400	400-4400	3300-4400	3400-4400	400-4400	400-4400
Beaver River I-27	300-3900	300-3900	N	N	300-2400	2500-3900
Beavercrow B-16	200-1700	200-1100	2000-2300	N	200-1700	200-1700
Beavercrow K-2	0-4000	0-4000	N	N	0-4000	N
Beavercrow O-15	200-1100	200-1100	N	N	200-1100	200-1100
Kotaneelee B-38	900-3300	3300-3900	900-3300	900-3300	N	900-3900
Kotaneelee E-37	3000-4200	3000-4200	N		N	3000-4200
Kotaneelee I-48	200-4400	200-4400	200-4400	200-4400	200-4400	200-4400
Kotaneelee I-48A	N	N	N	N	N	N
Kotaneelee L-38 & ST	0-4100	3000-3900	0-3800	0-3800	0-3800	900-3800
Kotaneelee M-17	200-1300	200-1300	200-1300	200-1300	200-1300	N
Kotaneelee P-50	100-4400	100-4400	N	N	<50m	100-4400
Merrill L-60	150-1650	150-1650	1150-1650	1150-1650	150-1650	150-1650
	1	1	6	6	3	3

Well Name	Mud Wt	WFT	LOT/FIT	Kicks
Beaver River G-1	N	Y	N	Y
Beaver River I-27	N	Y	N	N
Beavercrow B-16	Y	Y	N	N
Beavercrow K-2	N	Y	N	N
Beavercrow O-15	N	N	N	N
Kotaneelee B-38	Y	Y	Y	Y
Kotaneelee E-37	N	N	N	N
Kotaneelee I-48	Partial	N	Y	Partial
Kotaneelee I-48A	Y	Y	Y	N
Kotaneelee L-38 & ST	Y	Y	N	N
Kotaneelee M-17	Partial	N	N	Y
Kotaneelee P-50	N	Y	N	N
Merrill L-60	N	Y	N	N
	4	9	3	3

4 WELL-BY-WELL KEY OBSERVATIONS

At the end of this section is a single-well log panel for each well is included for reference showing the vertical coverage of the wireline data currently available. The tracks are ordered from left-to-right as follows;

- Track 1 Gamma ray (brown)
 - Track 2 Resistivity (blue)
 - Track 3 Density (red) & Neutron (black)
 - Track 4 Compressional Sonic (green)
 - Track 5 Calliper (black)
-

Beaver River G-1

- The overall wireline log coverage is excellent although density is only present below 3300 mMD.
- The well report confirms that density was only run over the lower portion of the well.
- The calliper data suggest the hole was not significantly out of gauge so the logged wireline magnitudes should be valid.
- 5 DSTs taken, 2 failed and the remaining 3 recorded valid pressures
- 2 Kicks are noted but only the depths are recorded and as the mudweight is not available the magnitude of the Kick cannot be estimated.
- No Leak-Off Tests (termed in the reports as Pressure Integrity Tests; PITs) or mudweights are noted in the report.
- The well report contains useful qualitative notes on well operations but does not contain any daily drilling reports (DDRs) that could be used to build a detailed drilling history.

Beaver River I-27

- The overall wireline log coverage is not optimum as while the gamma ray and sonic logs are present over the whole well, resistivity is only present in the upper half of the well, calliper is only present in the lower half of the well and density is not present at all.
- The well report confirms that induction (resistivity), sonic and calliper were acquired over the entire well, therefore the missing data maybe present and could be added to the project. No density data were acquired.
- The lack of shallow calliper removes the ability to assess hole stability, although it is noted the sonic does not show obvious signs of hole problems, e.g. low velocity zones where the hole is out of gauge.
- 8 DSTs taken, 5 failed and the remaining 3 recorded valid pressures.
- No LOTs or mudweights are noted in the report.
- The well report contains useful qualitative notes on well operations but does not contain any DDRs that could be used to build a detailed drilling history.

Beavercrow B-16

- Gamma ray, resistivity and calliper are present from 200-1700 mMD, the sonic is present from 200-1100 mMD and the density is present from 1950-2300 mMD. There is some resistivity measured over the same interval as the density but the magnitude is very high and does not appear to be valid data. The same observation can be made about the density data.
- The well report only contains planned logging runs and does not confirm what logs were actually run over what intervals. The daily summaries mention specific logs by

acronym only, e.g. FDC, HDT etc., which makes determining exactly what logs were acquired difficult but it does appear that there should be gamma ray and sonic over the deeper interval where density and resistivity is present. Also sonic was acquired down to 1700 mMD yet the log terminates at 1150 mMD for unknown reasons.

- The calliper records significant hole problems between 600-1350 mMD which has impacted the sonic and resistivity logs.
- 4 DSTs taken, 1 failed and the remaining 3 recorded valid pressures.
- No LOTs but mudweights are noted in the report.
- The well report contains useful qualitative notes on well operations but does not contain any DDRs that could be used to build a detailed drilling history.

Beavercrow K-2

- Excellent wireline coverage from surface to TD for gamma ray, resistivity and sonic, but the density and calliper are missing. The sonic and resistivity values are suspiciously high below 1400 mMD and may represent tool error or logs run through casing but do not appear to be valid magnitudes.
- The well report does not state if the suspect log sections were run through casing or not, but it does confirm that calliper data was acquired over the entire well which is missing from the current data package.
- The lack of calliper removes the ability to assess hole stability.
- 8 DSTs taken, 2 failed and the remaining 6 recorded valid pressures.
- No LOTs or mudweights are noted in the report.
- The well report contains useful qualitative notes on well operations but does not contain any DDRs that could be used to build a detailed drilling history.

Beavercrow O-15

- Wireline data are only present from 200-1100 mMD but the TD of the well is recorded as ~1727 mMD meaning the lower third of the well was not logged or the data are not available. Over the interval logged gamma ray, resistivity, sonic and calliper are complete but density is missing.
- The well report confirms that the log data described above was the only data acquired in this well.
- The calliper data record some hole problems from 700-1100 mMD which appear to affect the sonic data.
- No DSTs were run
- No LOTs or mudweights are noted in the report.
- The well report contains useful qualitative notes on well operations but does not contain any DDRs that could be used to build a detailed drilling history.

Kotaneelee B-38

- A complete deviation survey is available from surface down to TD
- Calliper is present over the whole well, gamma ray and density are present between 900-3300 mMD and sonic is present from 3300-3900 mMD only.
- The calliper records significant hole problems over much of the well which appear to have impacted the quality of the density data.
- 5 DSTs taken, 2 failed and the remaining 3 recorded valid pressures.
- Both LOTs and mudweights are noted in the report.
- The well report contains useful qualitative notes on well operations and also contains DDRs as an appendix that can be used to build a detailed drilling history.

Kotaneelee E-37

- There is no end of well report for this well, hence there are no deviation data, mudweights, direct pressure data, LOTs, kicks or DDRs. No information is present on what logging runs were made due to the lack of a well report.
- Wireline data is limited to 3000-4200 mMD of gamma ray, sonic and calliper only.
- The calliper data suggest possible hole problems between 3000-3400 mMD which appear to affect the sonic data.

Kotaneelee I-48

- A complete deviation survey is available from surface down to TD (located in files associated with the I-48A well)
- Excellent wireline coverage from surface to TD, gamma ray, resistivity, density, sonic, and calliper are all complete.
- The calliper log does indicate hole problems in the middle half of the well which appears to impact the sonic and density data.
- No direct pressure tests were made and no record of the mudweight is made, however, there is a detailed section on pore pressure in the well report which would allow for a partial mudweight record to be constructed including any Kick-type events.
- PITs were taken and are described within the pore pressure section of the report.
- The well report contains useful qualitative notes on well operations but does not contain any DDRs that could be used to build a detailed drilling history.

Kotaneelee I-48A

- A complete deviation survey is available from surface down to TD
- No wireline data are available for this well in the current data package.
- 8 DSTs taken, 5 failed and the remaining 3 recorded valid pressures.
- Gas shows are reported but kicks were not taken.
- Mudweight data are complete over the side track.
- A single leak-off test (LOT) was taken.
- The well report contains useful qualitative notes on well operations and also contains DDRs as an appendix that can be used to build a detailed drilling history.

Kotaneelee L-38 & ST

- Full deviation survey data are present for the main hole and the sidetrack(s).
- Excellent wireline data coverage from surface to TD for gamma ray data, and from surface to 3800 mMD (300 m above TD) for resistivity and density data. The sonic log is only present from 3000-3800 mMD with two logs present which do not match where present at the same depth hence are classed as suspect.
- The well report indicates that a dipole shear sonic tool was run from surface to TD yet only compressional sonic is present over at the base of the well. The study would benefit significantly from full compressional and shear sonic logs in this well.
- The sidetrack LAS data contain sonic logs in multiple files yet the data plot at different depths whilst all the files refer to the same sidetrack (ST3) hence there is some uncertainty that needs resolving.
- Calliper is present from 900-3800 mMD and the overall hole quality appears reasonable.
- The remainder of the side track data were not appraised as the data from the main hole has enough coverage and quality to be suitable for analysis.
- Pressure gauge data are available throughout the well.
- Mudweights are present from descriptive notes in various reports but there is no final table of mudweights.
- The well report contains useful qualitative notes on well operations and several sets of DDRs are available that can be used to build a detailed drilling history.

Kotaneelee M-17

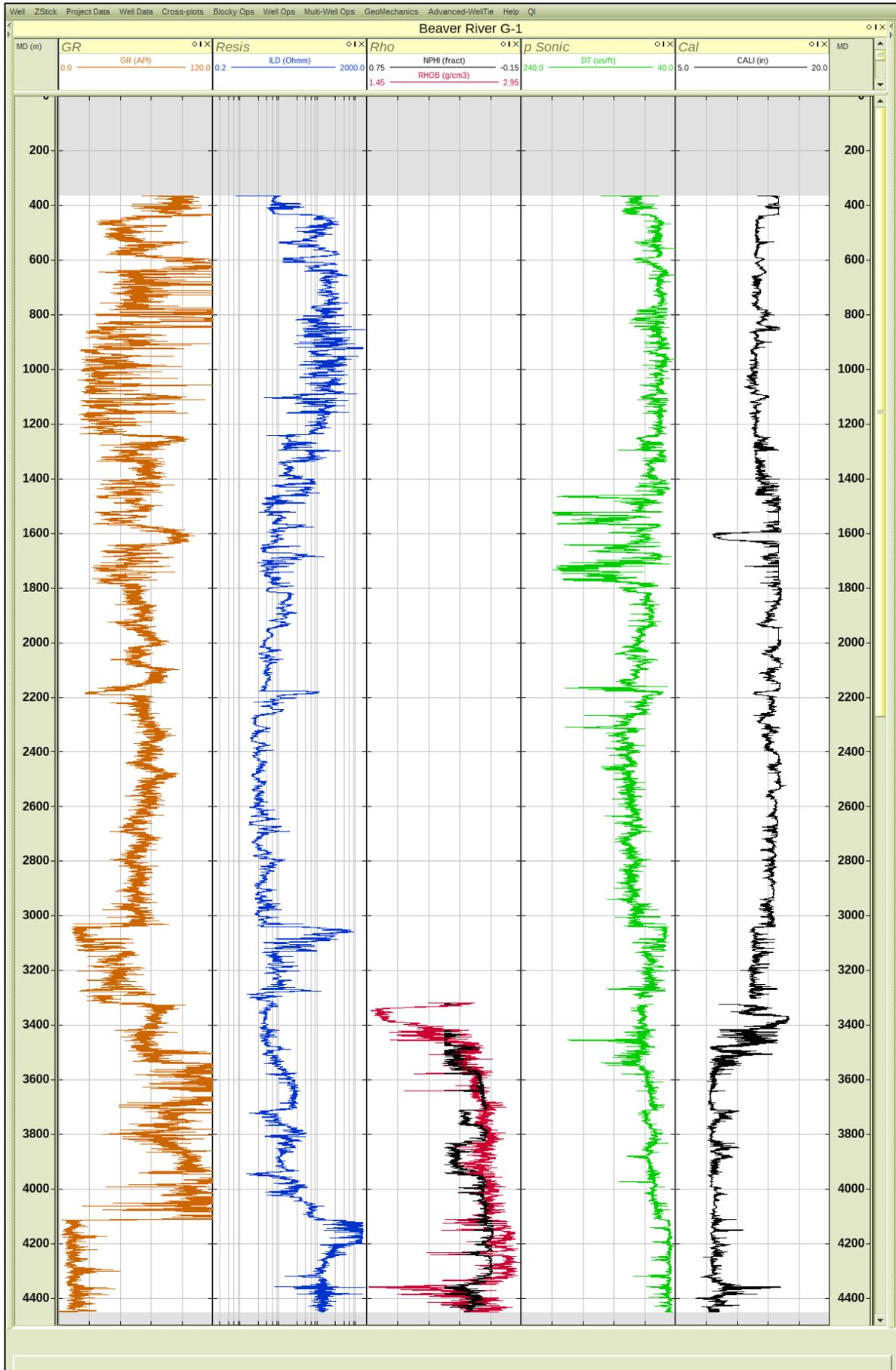
- Excellent wireline data coverage from surface to TD (shallow; 1325 mMD) with complete coverage of the gamma ray, resistivity, density and sonic logs. No calliper data are present.
- The well report does not list specific logging runs so the possibility of missing data cannot be assessed.
- The lack of calliper removes the ability to assess hole stability, although it is noted the sonic does not show obvious signs of hole problems, e.g. low velocity zones where the hole is out of gauge.
- There is a pore pressure discussion within the well report that notes gas and water influxes and how the influxes were controlled.
- No direct pressure tests or leak-off tests were taken and the mudweight used in the well is not tabulated in the well reports (some mudweights are included as comments within the DDRs but this not a complete record).
- The well report contains useful qualitative notes on well operations and also contains DDRs as an appendix that can be used to build a detailed drilling history.

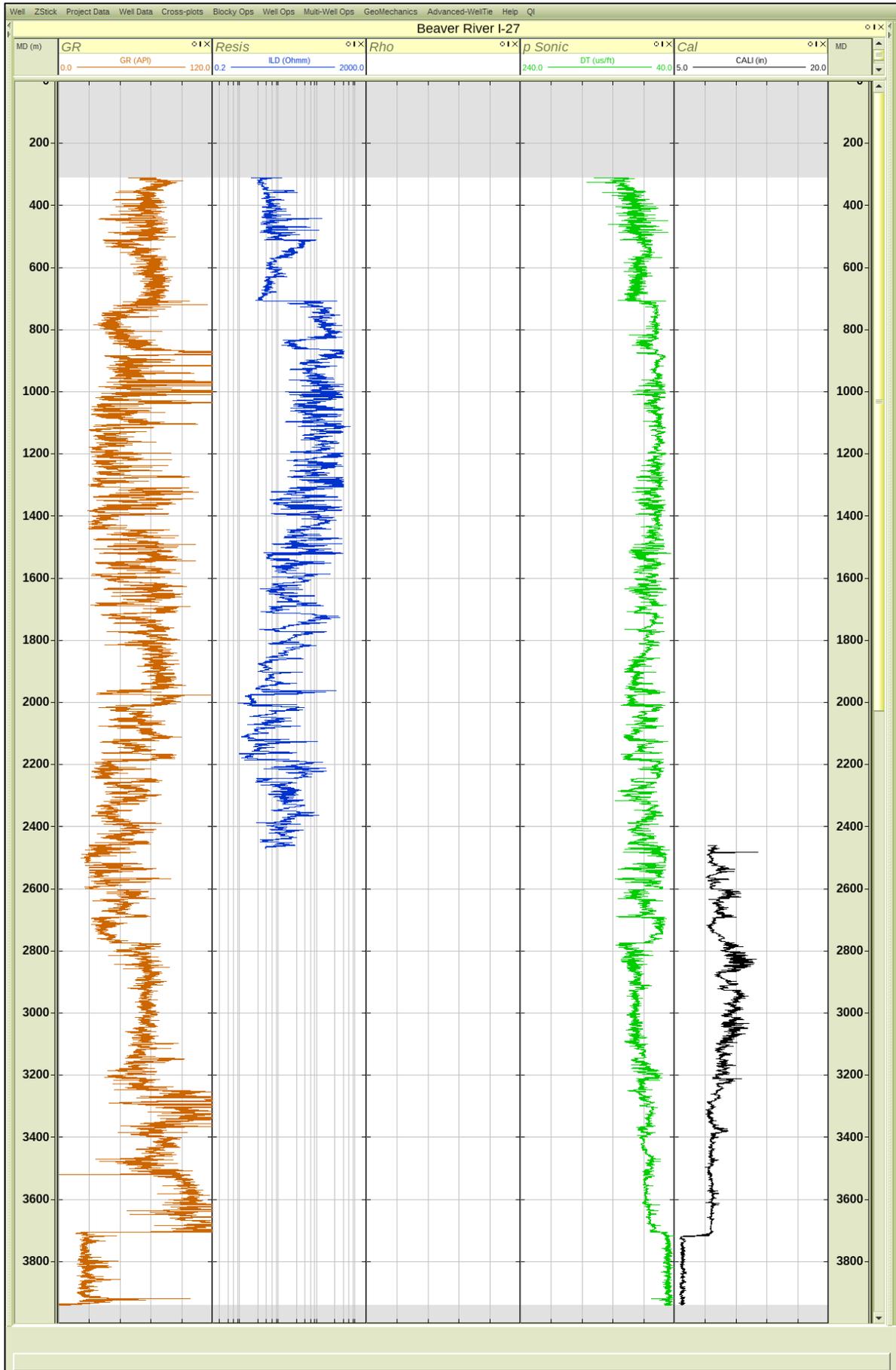
Kotaneelee P-50

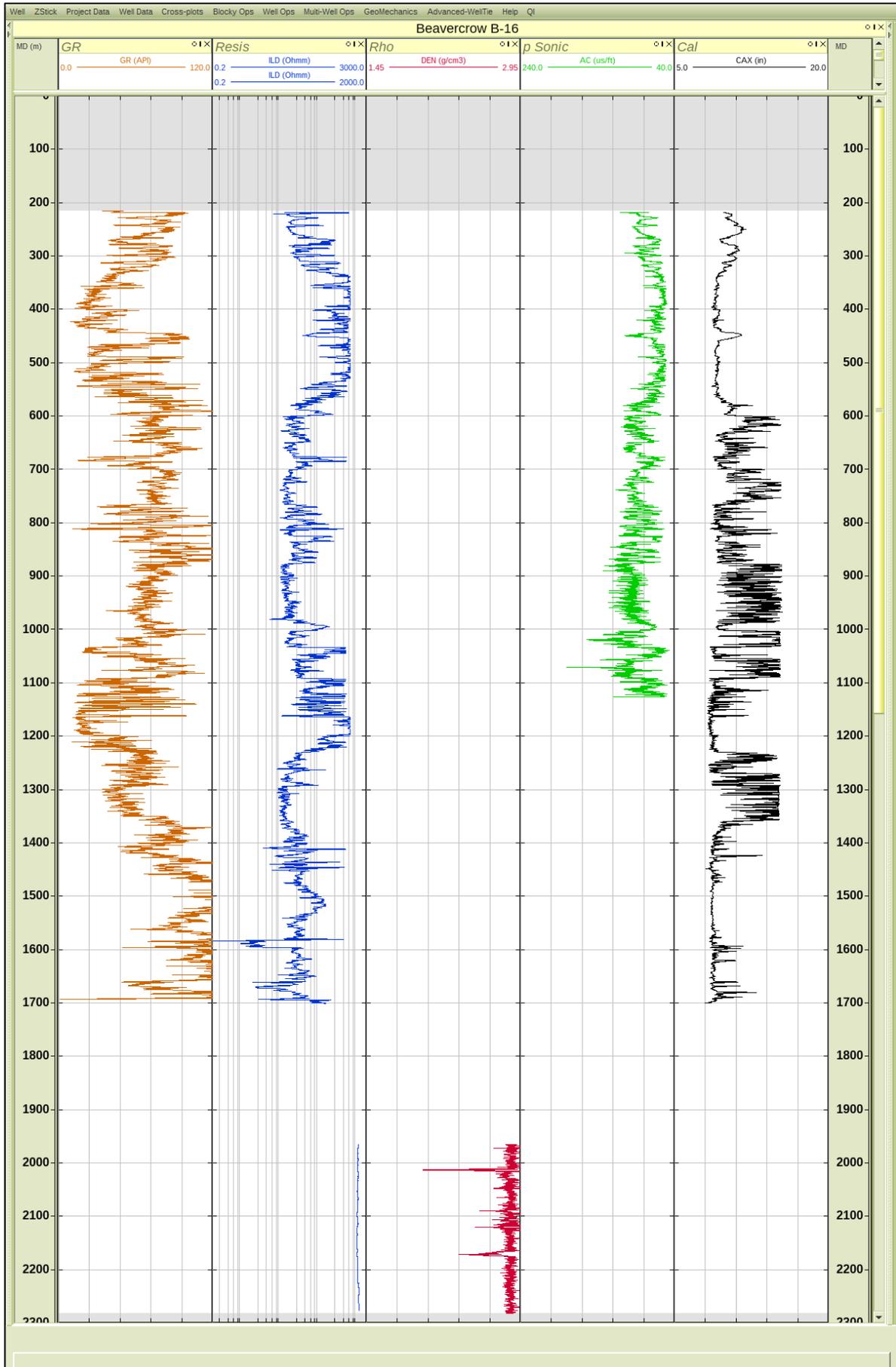
- Wireline data are present from surface to TD with complete coverage of the gamma ray, sonic and calliper logs but there are no density data and the resistivity is limited to less than 50 m close to the surface.
- The well report confirms that a continuous resistivity log should be present in the well, and that no density log was acquired.
- Some hole problems are noted from the calliper data, which affect the sonic adversely in the upper portion of the well but less so at depth.
- 1 successful DST taken.
- No LOTs or mudweights are noted in the report.
- The well report contains useful qualitative notes on well operations but does not contain any DDRs that could be used to build a drilling history.

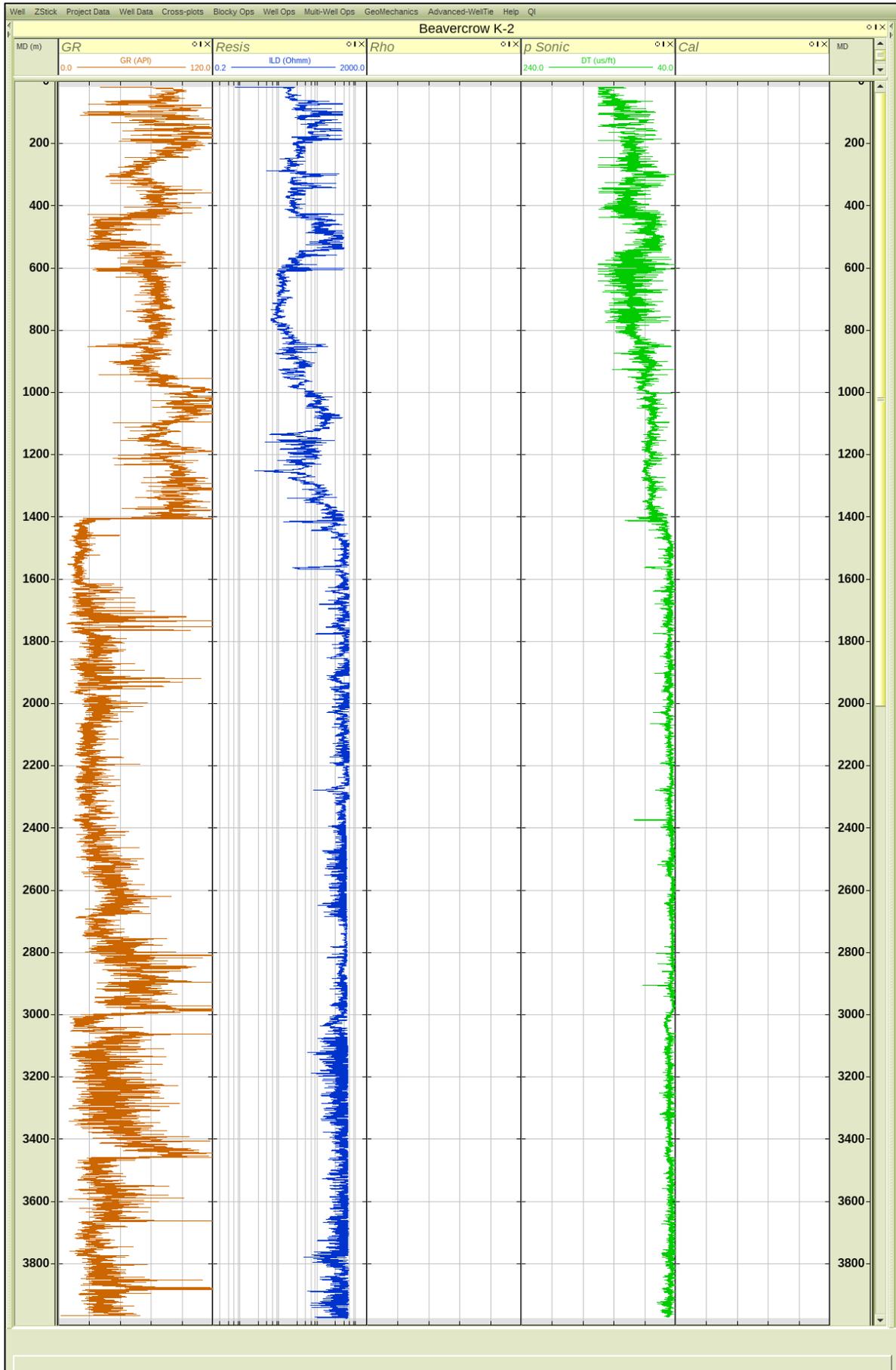
Merrill L-60

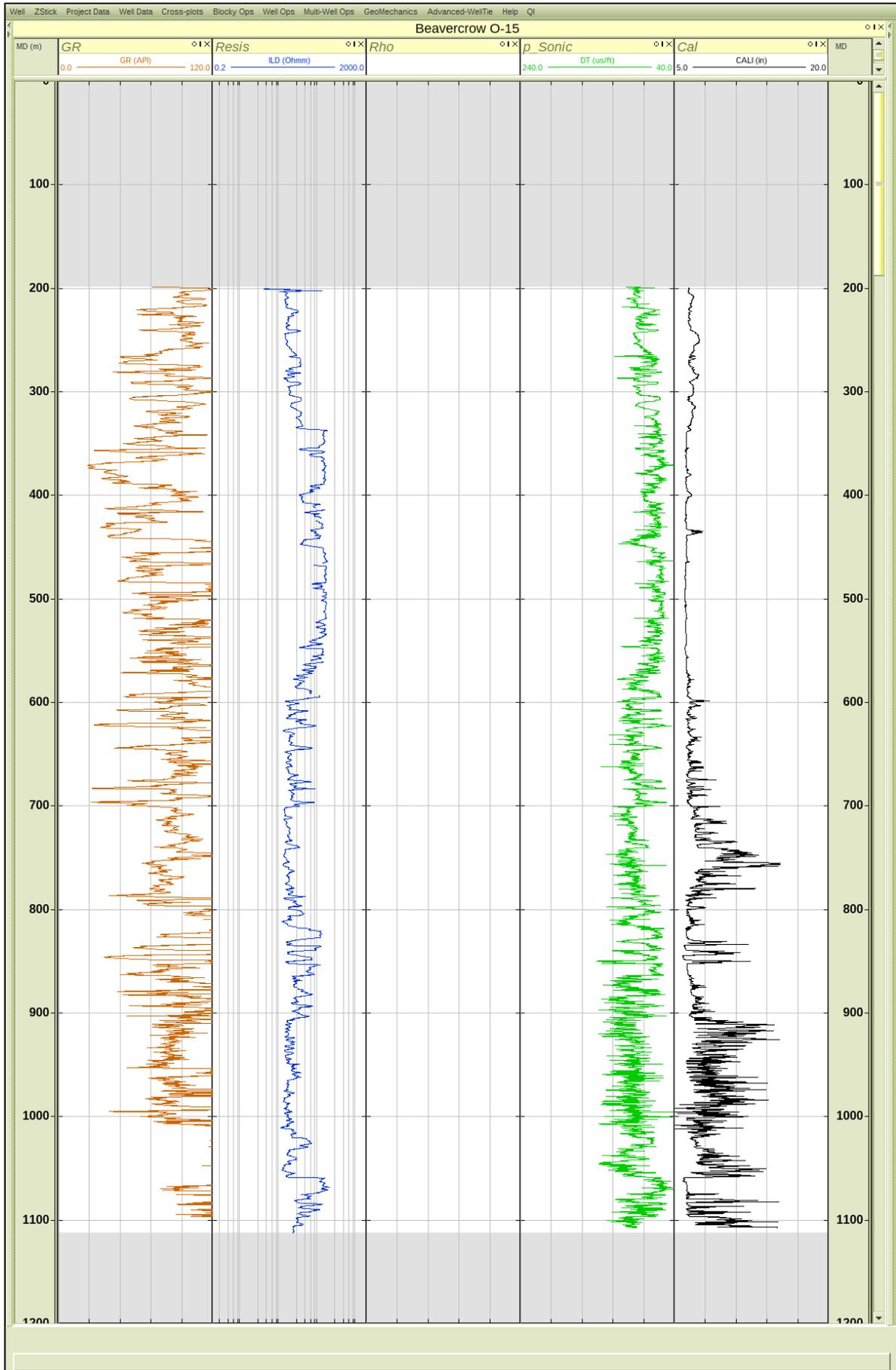
- Excellent wireline data coverage from surface to TD (shallow; 1625 mMD) with complete coverage of the gamma ray, resistivity, calliper, and sonic logs but there is only density data over 1150-1625 mMD.
- The well report confirms that the logs present match the logging runs performed for this well.
- Some minor hole problems may be present in the calliper data but do not appear to adversely affect the sonic and density logs.
- 1 DST was taken but the Final Shut In Pressure (FSIP) is very similar to the Initial and Final Hydrostatic Pressures (IHP; FHP) so the test may be invalid due to seal failure.
- No LOTs or mudweights are noted in the report.
- The well report contains useful qualitative notes on well operations but does not contain any DDRs that could be used to build a detailed drilling history.

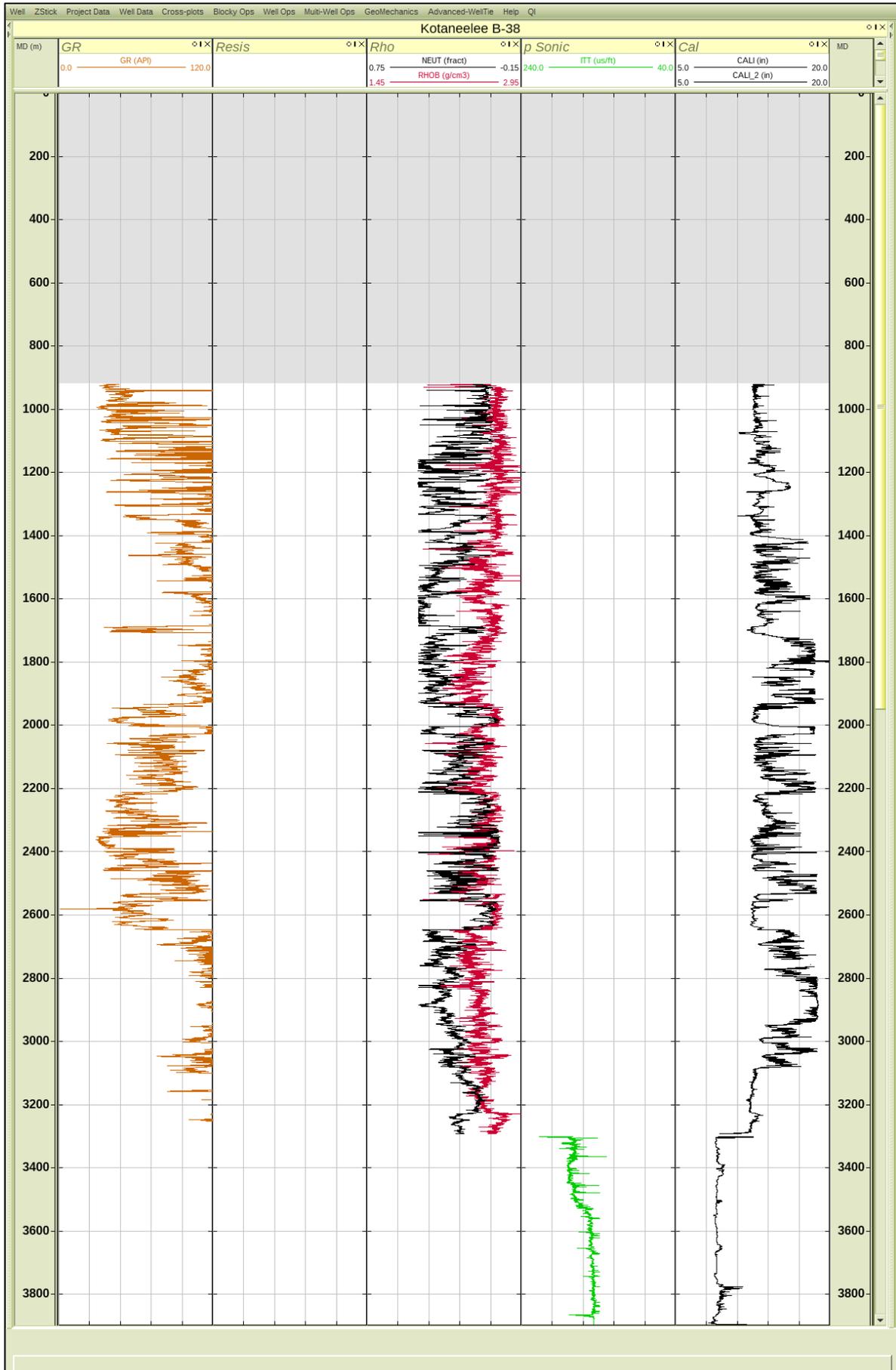


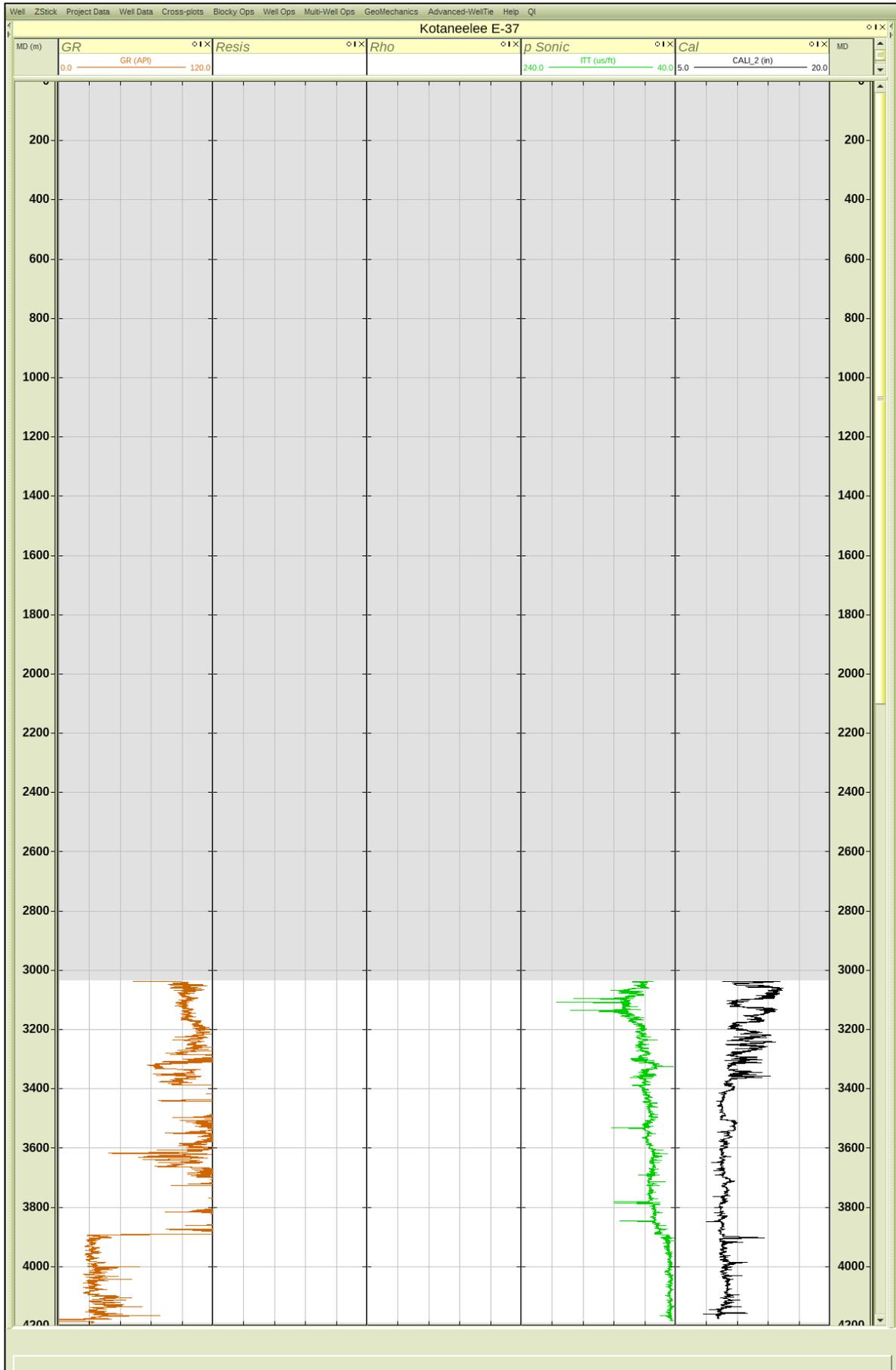


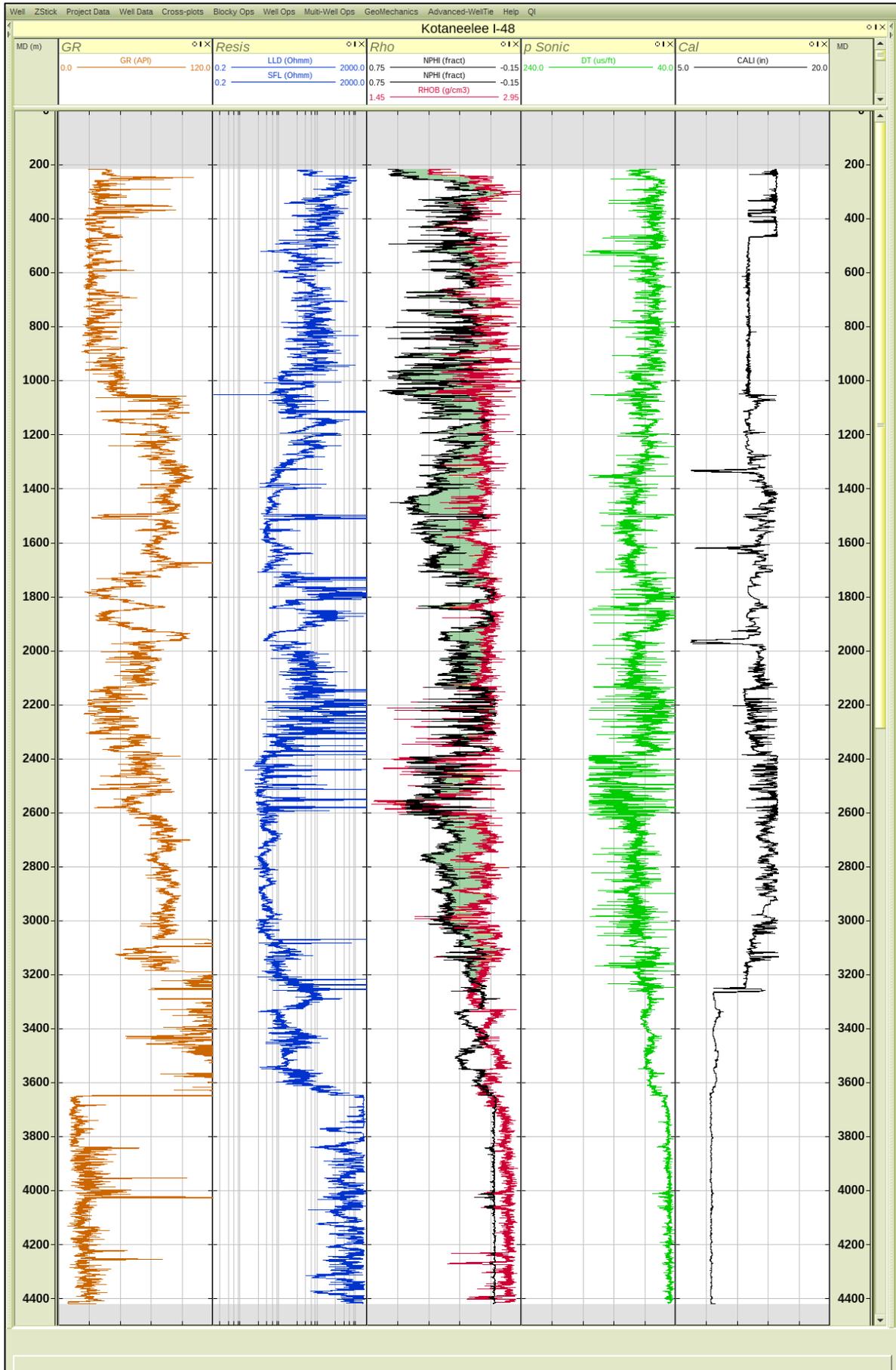


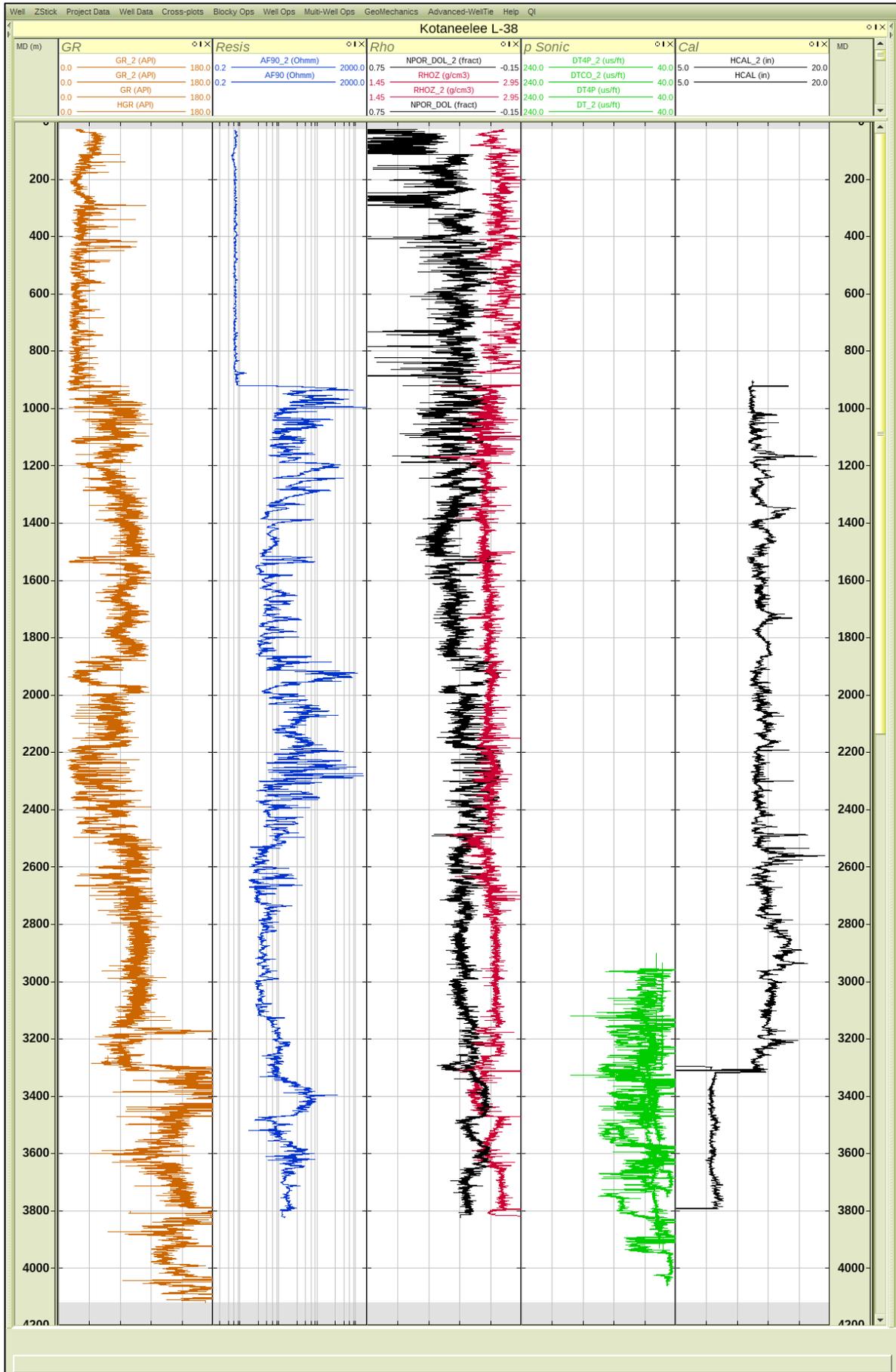


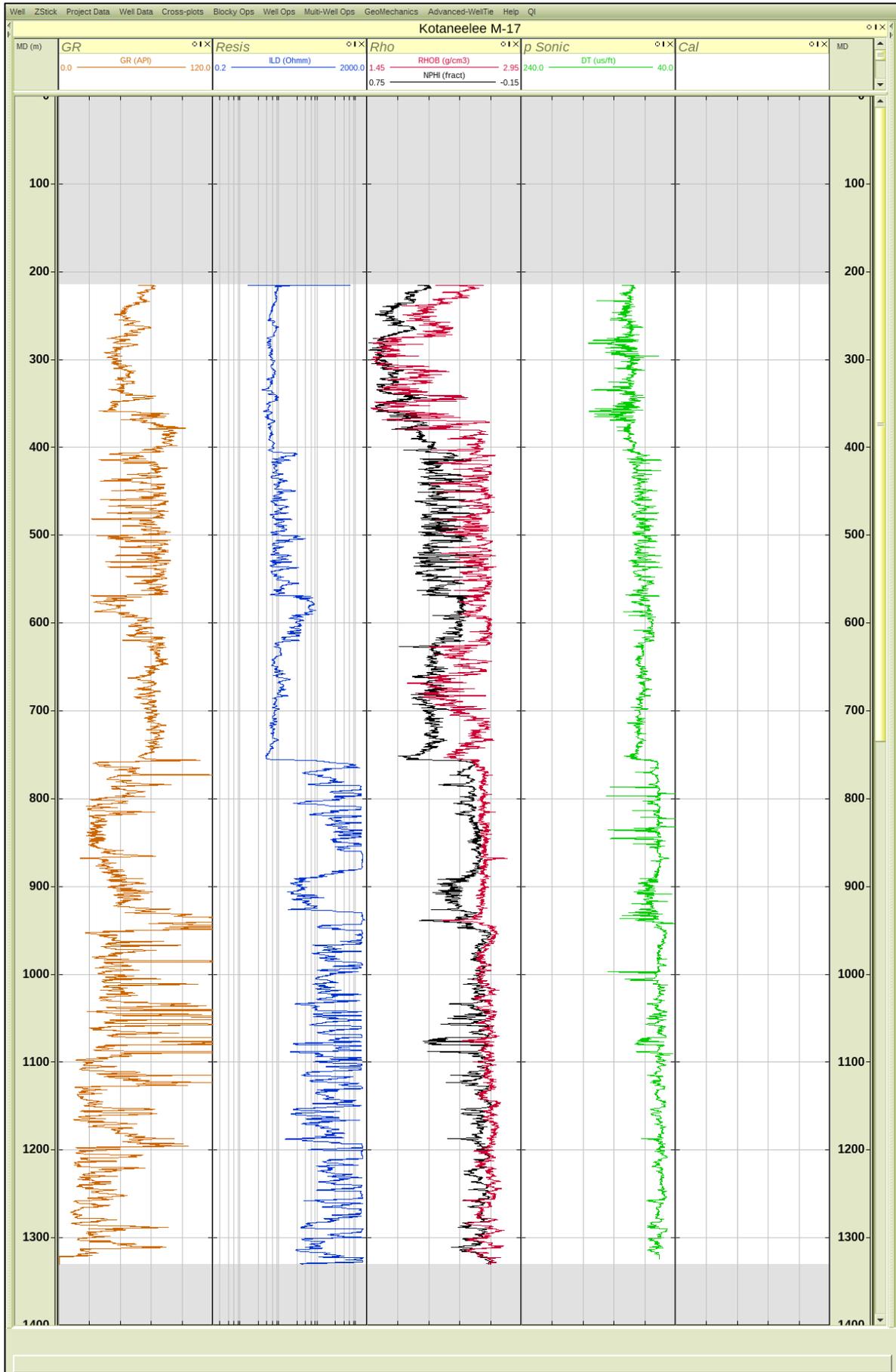


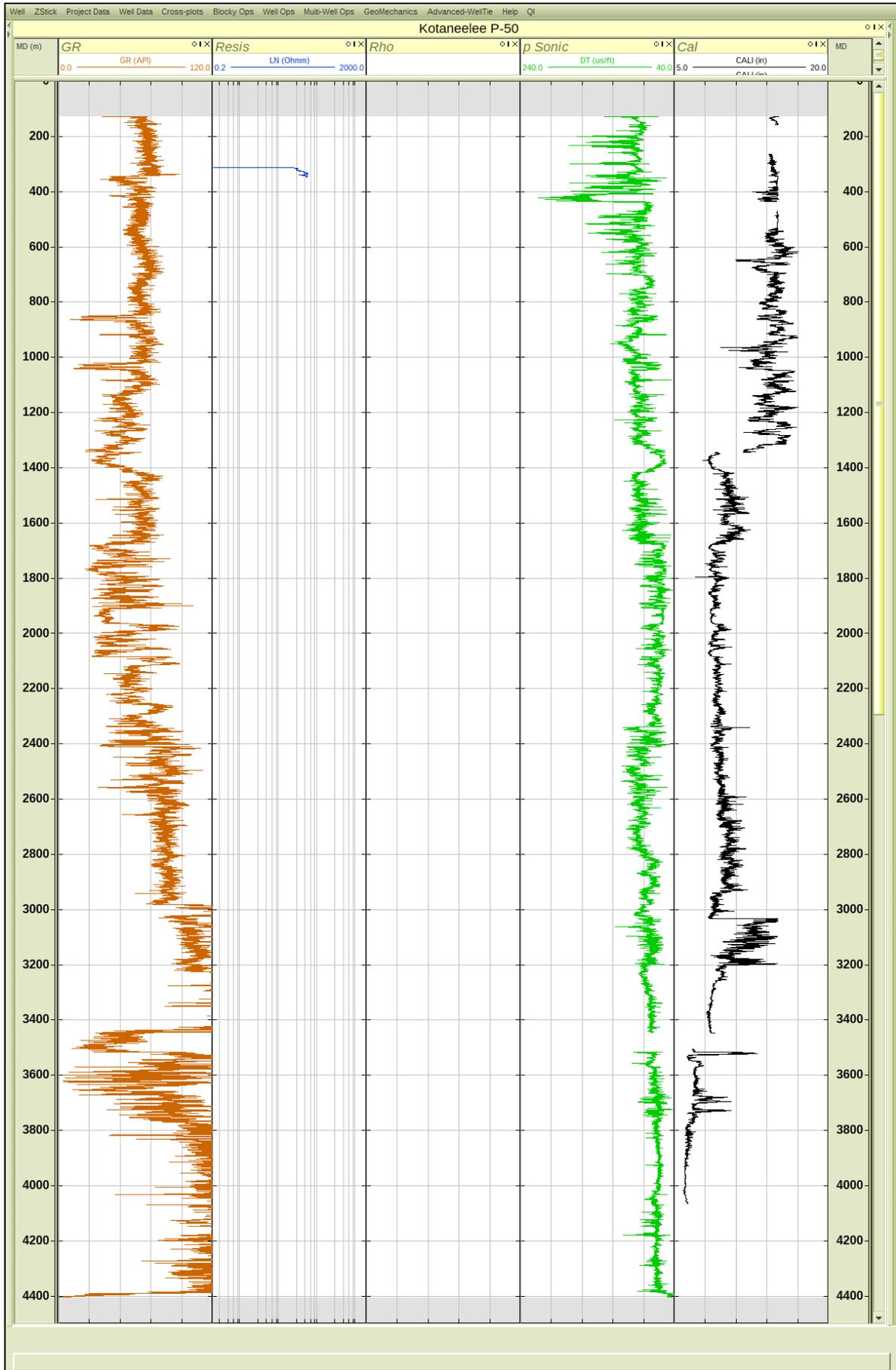


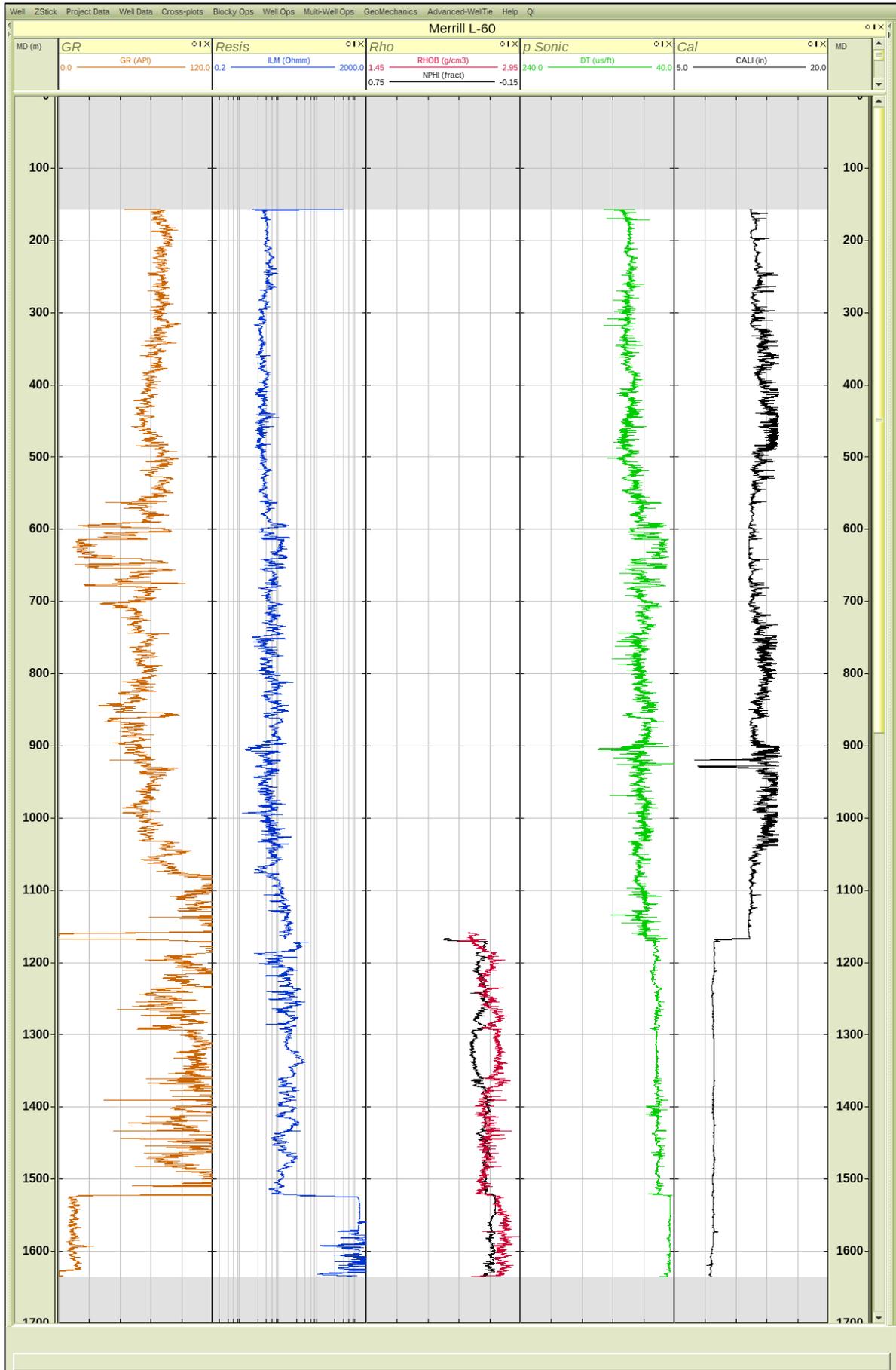












5 OVERALL COMMENTS ON THE DATA PACKAGE

5.1 IMPORTANT ISSUES

- The lack of daily drilling reports (only four wells have DDRs and a fifth well has a pore pressure description but not daily reports) means that the study is missing a source of vital calibration information and without this information the resolution of analysis in non-reservoir rocks will be lower. These descriptions are important in unconventional onshore plays as they provide important calibration data when estimating pore pressure in non-reservoir sections.

5.2 PRESSURE DATA SUMMARY

- Nine wells have direct pressure data, mostly DSTs, which provide some calibration data points for constructing a pore pressure model. These data have not been fully QC'd but given the age of the reports and the quality of the scanned images most values will have to be taken as recorded.
- Only three wells have fracture pressure data in the form of Pressure Integrity Tests (PITs) which is insufficient to characterise the fracture pressure or to generate a fracture pressure algorithm. Given the nature of the region and the aim to develop unconventional resources the inability to create a fracture pressure algorithm is not significant as the wells/area will require a full and detailed geomechanical earth model, which would ideally include shear velocity and image log data which are currently only available for one well.
- Only four wells have mudweight data available with little-to-no drill gas data present either. Two further wells have partial mudweight data in the form of pore pressure discussions in the well reports. These data, along with daily drilling reports (DDR) are vital to build a calibration dataset to test the pore pressure model against. Only four wells have DDRs, three of which also contain mudweights which could provide a proof-of-concept study for the purposes of pore pressure characterisation.

5.3 WIRELINE DATA SUMMARY

- Gamma ray logs are present in all wells with LAS data and typically cover the entirety of the vertical extent of the wells. The logs appear to pick out shales and sands allowing for volume logs (Vshale) to be estimated.
- Volume log generation would be calibrated to the lithology information, which is a combination of cuttings descriptions in the well reports and hard copy Canstrat logs supplied by the YGS and provide highly valuable information. Both data sources would require significant time to digitise the interpretations into a digital format that could be loaded into the software.
- Wells with minimal or no density log coverage will require a model-driven solution to build an overburden (vertical stress) curve. Those wells with density will be used to construct the model providing sufficient ground truth to the model but the lack of measured data will induce some uncertainty although this should be minimal. A multi-well plot of all the density data indicates that the data coverage is sufficient to

construct a density-depth model applicable to all wells (Figure 2) but the data are dominantly from Kotaneelee H-38, I-48, and L-38 as they have close to full well coverage, the remaining four wells with density data have partial well coverage only. It is noted that the data show a classic signature of rocks that have undergone uplift and erosion as the logs record over-consolidated logs near to surface.

- The sonic velocity log is the primary, but not the only, data used to estimate pore pressure. The overall coverage is good although it does vary significantly from well to well (Figure 3), meaning that in some wells the pore pressure estimations will not cover much vertical extent. In such cases it may be possible to supplement the coverage with density-derived pore pressure estimates, where data allow. Much like the density data the effects of uplift and erosion are clearly evident in the sonic data. The result of the uplift and erosion means that the data appear to record low pore pressure despite known presence of higher pressure (kicks and influxes) which will require careful calibration during the pore pressure derivation process.
- Resistivity data are routinely used in conventional pore pressure estimate, however, they are rarely used onshore as the data tend to be more variable from well-to-well which induces more scatter in the overall interpretations. As the data coverage is typically good for the wells of the study, a resistivity interpretation would be useful, as well as using the data to assess *in-situ* fluids where possible.
- Calliper data are present in most wells but the vertical coverage does not always match the other log data. Calliper data are most useful when assessing whether the borehole was in gauge when it was being logged. If the hole quality is low, i.e. borehole breakout has occurred, this typically results in problems acquiring valid density and sonic data which are critical for pore pressure analysis. As is noted above, several wells show hole issues in the log data that will require sections of log data to be removed before analysis can continue.

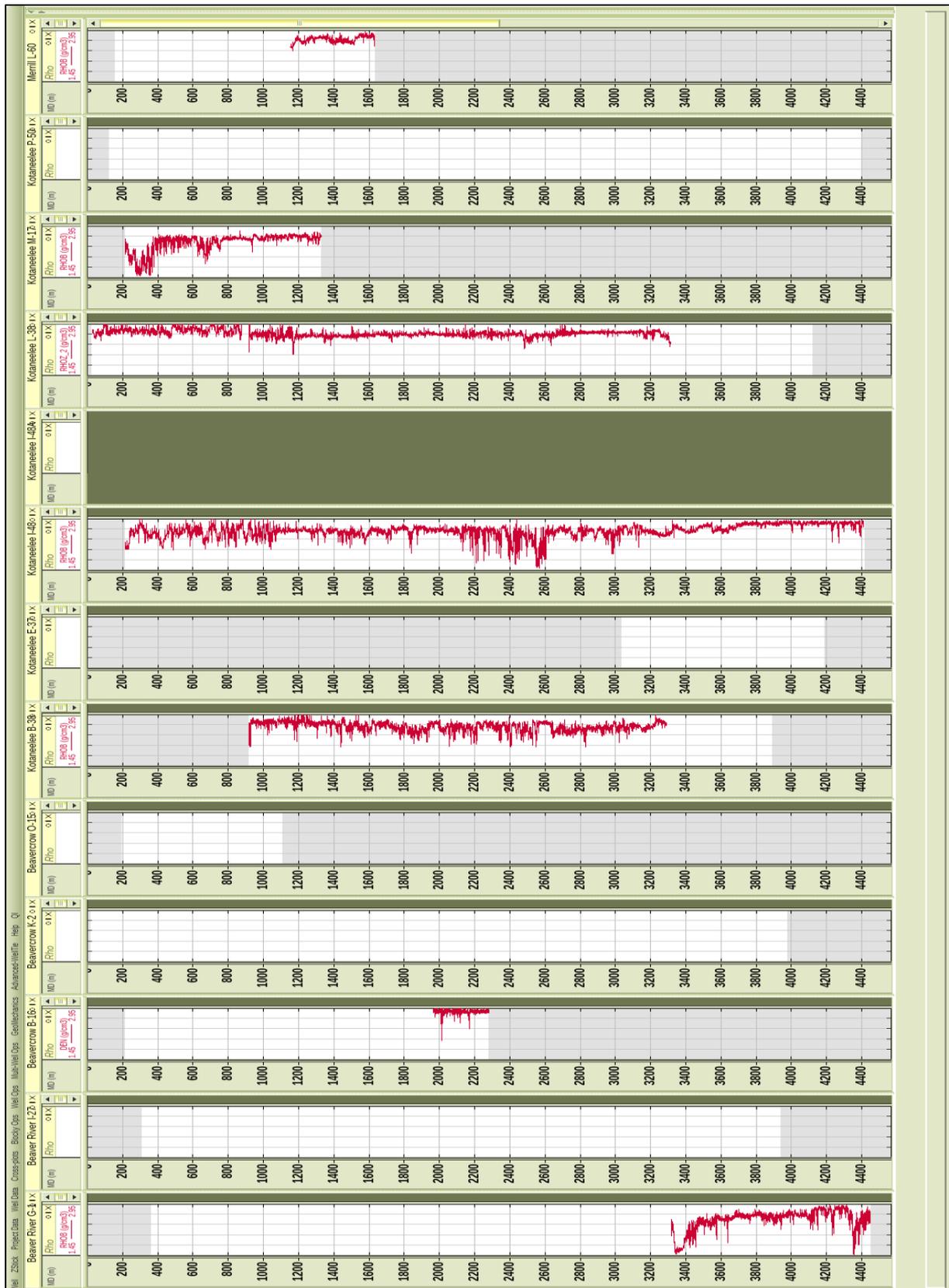


Figure 2: Density log coverage for all the wells; depths in MD. The overall coverage is biased towards 3 wells with full vertical coverage, and a total of 7 out of 13 wells containing density. White intervals represent the depth range of the LAS data for the well as a whole, i.e. other logs may have more extent; dark green indicates no LAS data present.

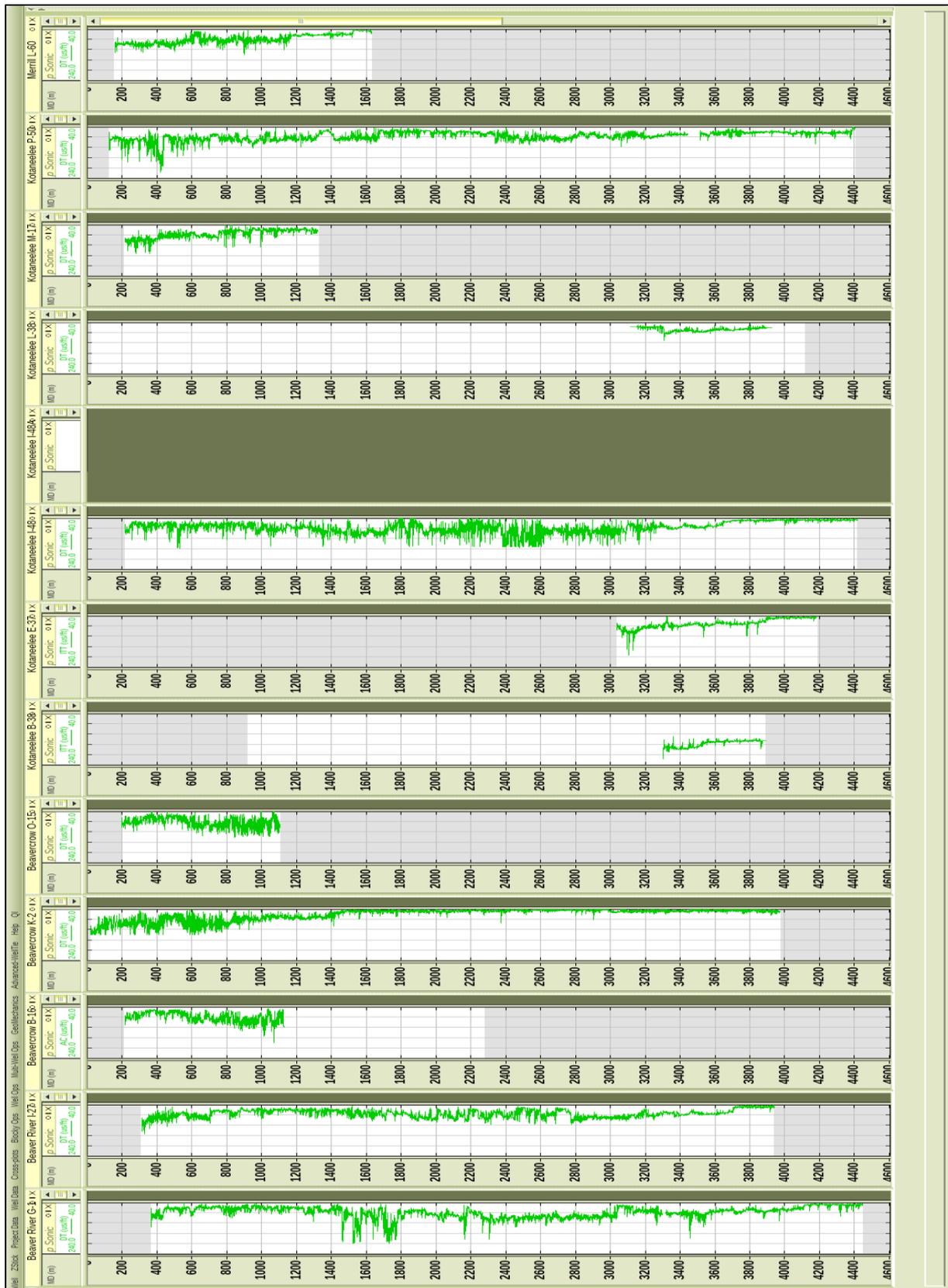


Figure 3: Sonic log coverage for all the wells; depths in MD. The overall coverage is excellent with 12 out of 13 wells containing sonic and 8 of those having sonic over the whole well. White intervals represent the depth range of the LAS data for the well as a whole, i.e. other logs may have more extent; dark green indicates no LAS data present.