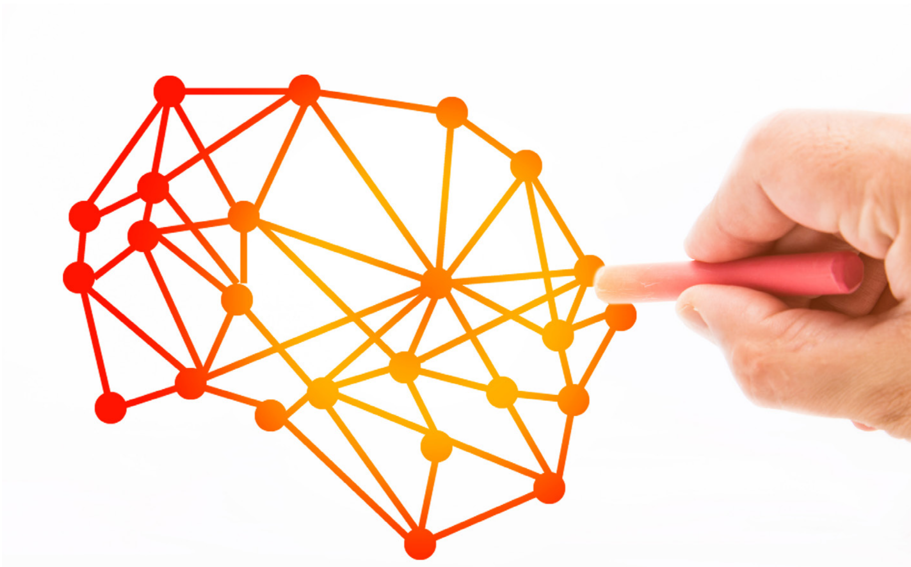
Using Natural Language Processing to Convert Mud-Log Chip Descriptions to Useful Data Tables

Marcelo Guarido, David Emery, and Kris Innanen

Banff, December 2nd, 2022

www.crewes.org



Today's Agenda

Part 1:	Chip Descriptions to Table
Part 2:	Synthetic DTC
Part 3:	Conclusions

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Part 1:

CHIP DESCRIPTIONS TO TABLE

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Chip Descriptions in Mud-Logging

- Part of the mud-logging report
- Descriptive mineral analysis per depth interval
- Used by interpreters
- Supporting document
- Usually in PDF files
- Hard to use as data

PDF

ConocoPhillips

Cuttings Descriptions Report

Well Name : Poseidon-2	**Print Date** 8/07/2010
Wellsite Geologist(s) : M Boyd M Ortiz S Phillips J Bardelosa M Ortiz M Warrington	

Interval (m)	%	Lithology / Show Descriptions	Ca (%)	Mg (%)
Main				
2429.0 - 2430.0	100	**ARGILLACEOUS CALCILUTITE:** (Sample from Bit Junk Slot), dark greenish grey, firm, sticky, plastic, 40-50% clay material, strongly calcareous, grading to Marl?.	52	0
2430.0 - 2440.0	70	**CALCARENITE:** yellowish grey, very pale brown to very pale orange, trace off white to very light grey, moderately hard, blocky to sub-blocky, sucrosic in part, occasional fine calcite grains, 2% pyrite nodules, rare very fine disseminated pyrite in part.	78	0
	30	**CEMENT:**		
2440.0 - 2450.0	95	**CALCARENITE:** as above, very pale orange to very pale brown, trace to 2% pyrite nodules & forams, 3% chert in part, very fine quartz grains in part.	79	1
	5	**CALCILUTITE:** white, off white, firm to generally moderately hard, blocky to subblocky, cryptocrystalline.		
2450.0 - 2460.0	100	**CALCARENITE:** very pale brown to very pale orange, rare off white to white, moderately hard, sub-blocky to trace blocky, cryptocrystalline when white, occasionally sucrosic, trace pyrite nodules, trace forams and fossil fragments.	84	1
2460.0 - 2470.0	100	**CALCARENITE:** as above, very fine quartz grain inclusions in part.		
2470.0 - 2480.0	95	**CALCARENITE:** as above, very pale brown to very pale orange, moderately hard, sub-blocky to blocky, occasionally sucrosic, trace pyrite nodules.		
	5	**CALCILUTITE:** medium light grey, medium grey, firm to moderately hard, sub-blocky to blocky, slight to moderately argillaceous,		
2480.0 - 2490.0	95	**CALCARENITE:**	84	1
	5	**CALCILUTITE:** as above.		
2490.0 - 2500.0	97	**CALCARENITE:** as above, 3% chert.	87	1
	3	**CHERT:** very pale to pale orange, occasionally translucent, hard, angular, conchoidal fracture.		
2500.0 - 2510.0	95	**CALCARENITE:** as above, very pale brown to very pale orange, rare off white to white, moderately hard to brittle, sub-blocky to trace blocky, predominant fine fragments, cryptocrystalline to sucrosic, 5% chert.	87	1
	5	**CHERT:** as above.		
2510.0 - 2520.0	97	**CALCARENITE:** as above.	85	1
	5	**CHERT:** as above.		
2520.0 - 2530.0	92	**CALCARENITE:** as above, very pale brown to very pale orange, rare off white and pale orange, moderately hard to brittle, sub-blocky to trace blocky, predominant fine fragments, cryptocrystalline to sucrosic, 3-5% chert fragments.		
	5	**CALCILUTITE:** medium light grey, medium grey, medium bluish grey, firm, sub-blocky to occasionally blocky, slightly argillaceous,		
	3	**CHERT:** as above.		
2530.0 - 2540.0	90	**CALCARENITE:** as above.		
	5	**CALCILUTITE:** as above.		
	5	**CHERT:** as above.		
2540.0 - 2550.0	95	**CALCARENITE:** as above.	82	1
	5	**CHERT:** as above.		
2550.0 - 2560.0	98	**CALCARENITE:** very pale brown, yellowish grey, rare white, moderately hard, predominantly fine fragments, occasionally medium, sub-blocky to blocky, nil to trace chert, Claystone and orange translucent fragments.		
	2	**CHERT:** as above.		

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PDF to Table

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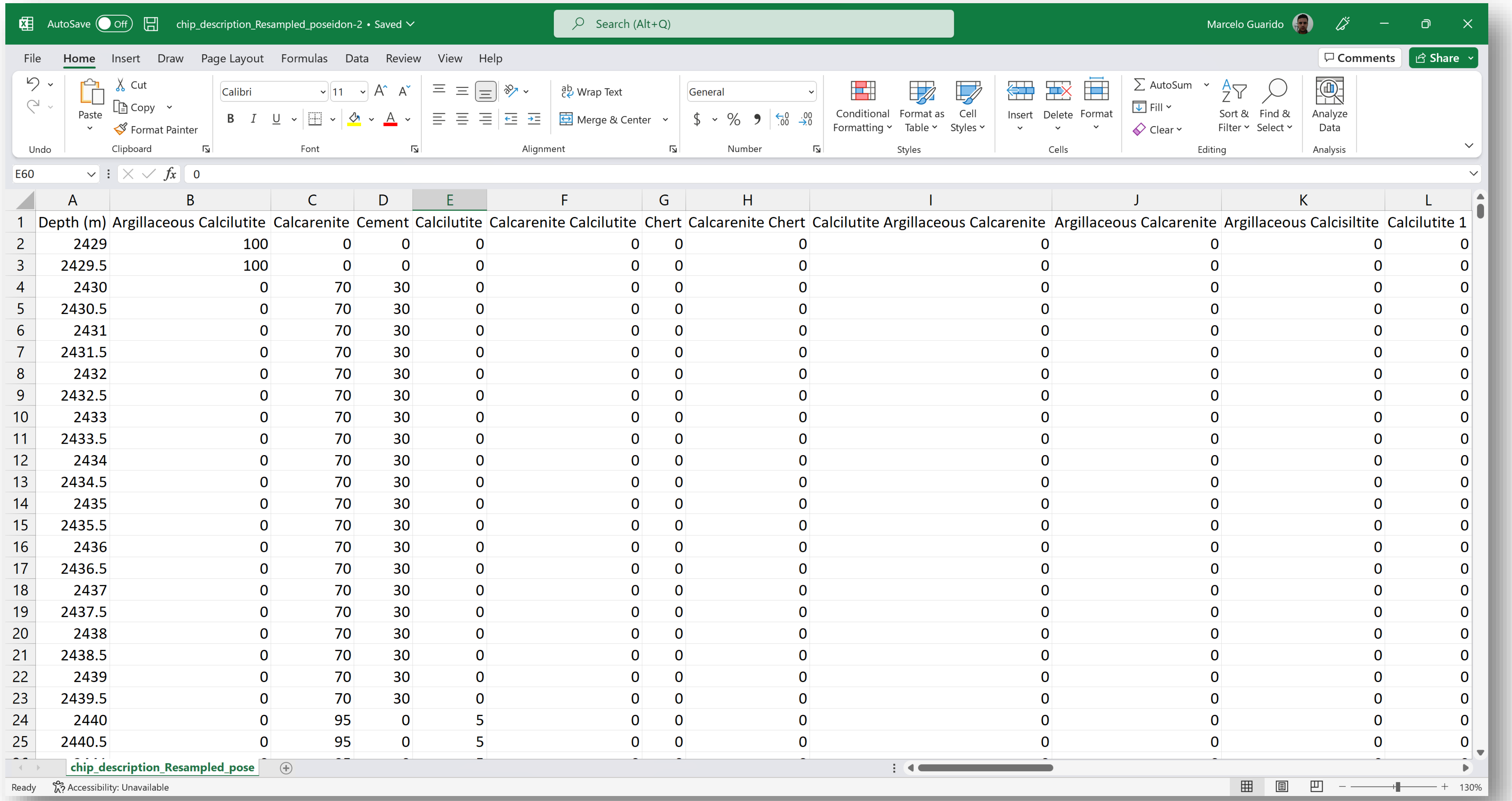
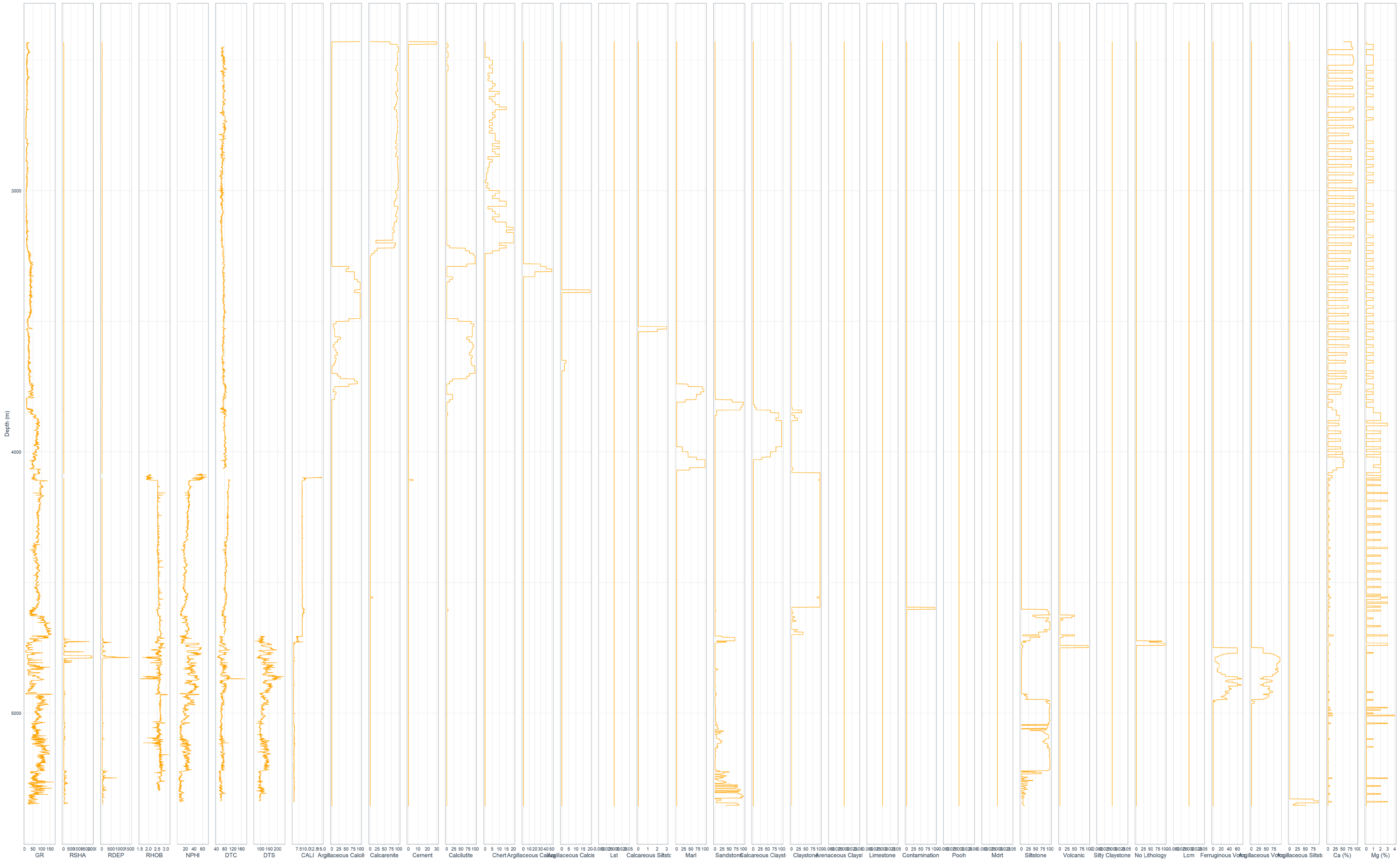


	A	B	C	D	E	F	G	H	I	J	K	L
1	Depth (m)	Argillaceous Calcilutite	Calcarenite	Cement	Calcilutite	Calcarenite Calcilutite	Chert	Calcarenite Chert	Calcilutite Argillaceous Calcarenite	Argillaceous Calcarenite	Argillaceous Calcisiltite	Calcilutite 1
2	2429	100	0	0	0	0	0	0	0	0	0	0
3	2429.5	100	0	0	0	0	0	0	0	0	0	0
4	2430	0	70	30	0	0	0	0	0	0	0	0
5	2430.5	0	70	30	0	0	0	0	0	0	0	0
6	2431	0	70	30	0	0	0	0	0	0	0	0
7	2431.5	0	70	30	0	0	0	0	0	0	0	0
8	2432	0	70	30	0	0	0	0	0	0	0	0
9	2432.5	0	70	30	0	0	0	0	0	0	0	0
10	2433	0	70	30	0	0	0	0	0	0	0	0
11	2433.5	0	70	30	0	0	0	0	0	0	0	0
12	2434	0	70	30	0	0	0	0	0	0	0	0
13	2434.5	0	70	30	0	0	0	0	0	0	0	0
14	2435	0	70	30	0	0	0	0	0	0	0	0
15	2435.5	0	70	30	0	0	0	0	0	0	0	0
16	2436	0	70	30	0	0	0	0	0	0	0	0
17	2436.5	0	70	30	0	0	0	0	0	0	0	0
18	2437	0	70	30	0	0	0	0	0	0	0	0
19	2437.5	0	70	30	0	0	0	0	0	0	0	0
20	2438	0	70	30	0	0	0	0	0	0	0	0
21	2438.5	0	70	30	0	0	0	0	0	0	0	0
22	2439	0	70	30	0	0	0	0	0	0	0	0
23	2439.5	0	70	30	0	0	0	0	0	0	0	0
24	2440	0	95	0	5	0	0	0	0	0	0	0
25	2440.5	0	95	0	5	0	0	0	0	0	0	0

PDF to Table



Depth (m)
3000
4000
5000
GR
RSHA
RDEP
RHOB
NPHI
DTC
DTS
CALI
Calcarenite
Cement
Calcilutite
Lst
Marl
Limestone
Contamination
Pooh
Mdrt
Siltstone
Volcanic
Silty Claystone
No Lithology
Lcm
Ca (%)
Mg (%)

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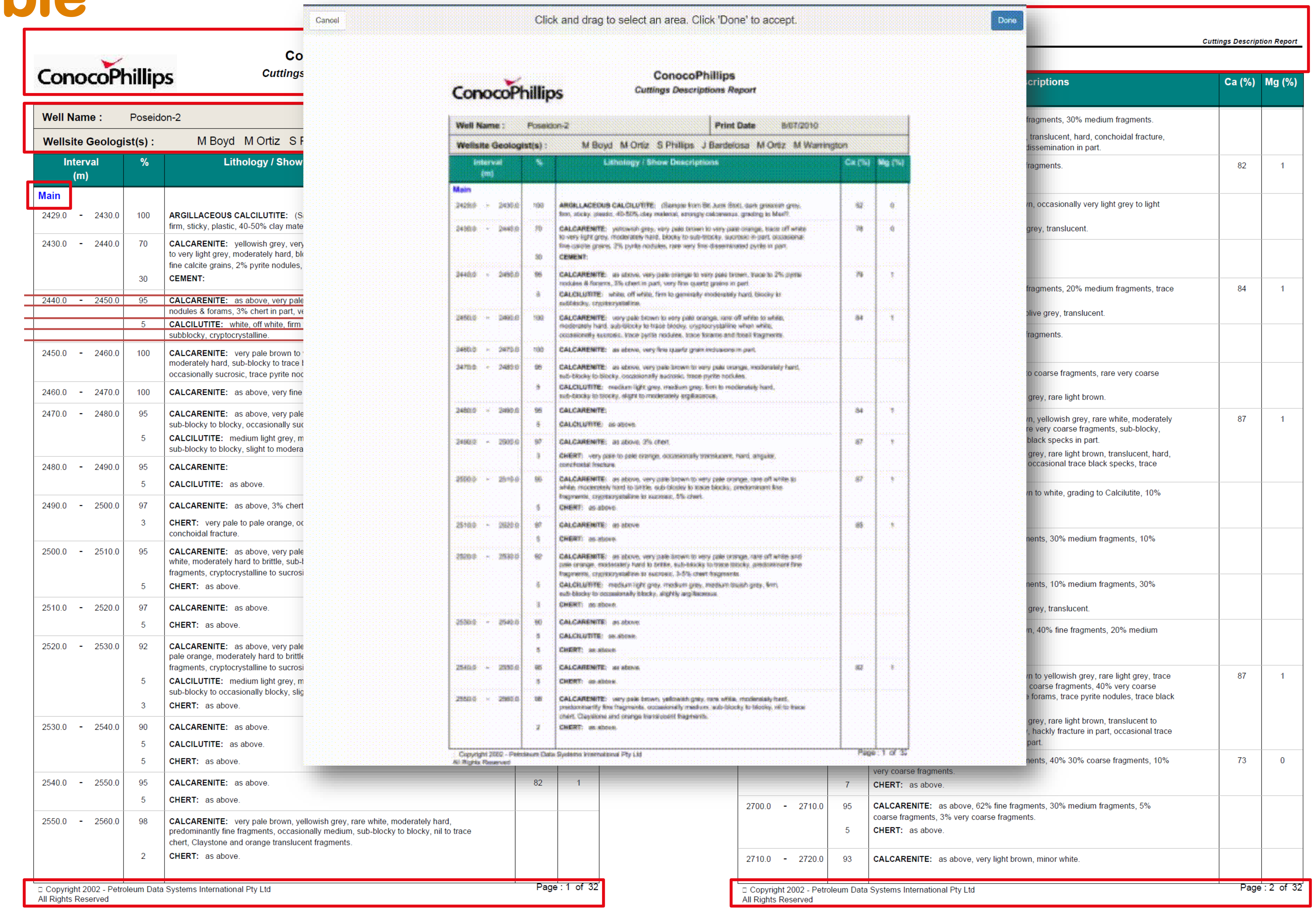
PDF to Table



PDF to Table

SANDSTONE: light olive grey to pale yellowish brown, olive grey, translucent, predominantly moderately hard aggregates, predominantly fine to commonly medium, moderately well sorted, sub-rounded to occasionally sub-angular, moderately strong siliceous cement, minor silty matrix in part grading to trace very fine arenaceous SILTSTONE, predominantly fair to good visible porosity, poor porosity in very fine to silty aggregates, no fluorescence. **SILTSTONE:** olive black, commonly grading to olive grey, firm, blocky, weakly calcareous, moderately argillaceous, commonly arenaceous.

REGEX → Regular Expression

[A-Z]+:?([A-Z]+[A-Z \d]+:)

PDF to Table

Tabulizer

- Select the table on the first page
- Read other pages
- Extract long table

Processing

- Regularize table and merge rows
- Locate minerals with NLP and separate into columns
- Feed the new columns with percentages

Export

- Resample to the desired sample rate
- Export to CSV

PDF to Table

Radiant | Data | Design | Basics | Model | Multivariate | Report | Project: (None)

Datasets:

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- [ ] Add/edit data description
- [ ] Rename data

Display: preview · str · summary

Load data of type:

rds | rda | rdata

Browse... No file selected

Save data to type:

csv

Save

- [ ] Show R-code
- [ ] Remove data from memory

Manage | View | Visualize | Pivot | Explore | Transform | Combine

Data preview

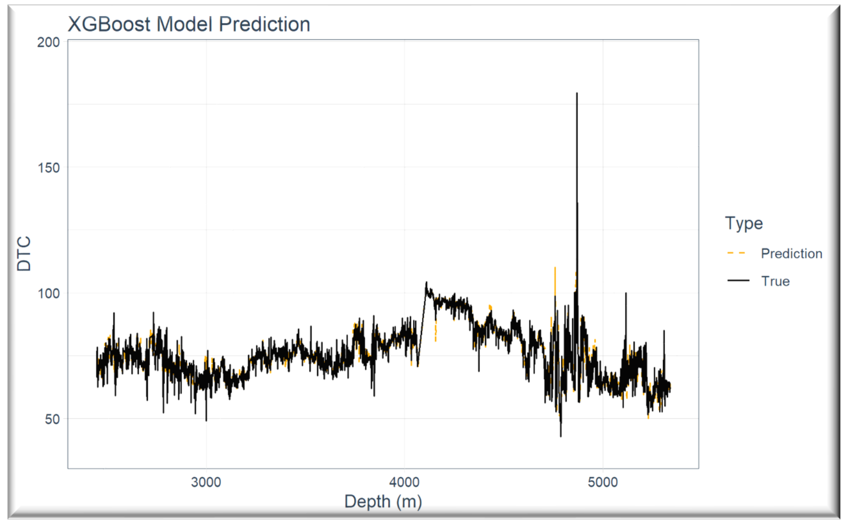
	A	B	C	D	E	F	G	H	I	J	K	L
1	Depth (m)	Argillaceous Calcilutite	Calcarenite	Cement	Calcilutite	Calcarenite Calcilutite	Chert	Calcarenite Chert	Calcilutite Argillaceous Calcarenite	Argillaceous Calcarenite	Argillaceous Calcisiltite	Calcilutite 1
2	2429	100	0	0	0	0	0	0	0	0	0	0
3	2429.5	100	0	0	0	0	0	0	0	0	0	0
4	2430	0	70	30	0	0	0	0	0	0	0	0
5	2430.5	0	70	30	0	0	0	0	0	0	0	0
6	2431	0	70	30	0	0	0	0	0	0	0	0
7	2431.5	0	70	30	0	0	0	0	0	0	0	0
8	2432	0	70	30	0	0	0	0	0	0	0	0
9	2432.5	0	70	30	0	0	0	0	0	0	0	0
10	2433	0	70	30	0	0	0	0	0	0	0	0
11	2433.5	0	70	30	0	0	0	0	0	0	0	0
12	2434	0	70	30	0	0	0	0	0	0	0	0
13	2434.5	0	70	30	0	0	0	0	0	0	0	0
14	2435	0	70	30	0	0	0	0	0	0	0	0
15	2435.5	0	70	30	0	0	0	0	0	0	0	0
16	2436	0	70	30	0	0	0	0	0	0	0	0
17	2436.5	0	70	30	0	0	0	0	0	0	0	0
18	2437	0	70	30	0	0	0	0	0	0	0	0
19	2437.5	0	70	30	0	0	0	0	0	0	0	0
20	2438	0	70	30	0	0	0	0	0	0	0	0
21	2438.5	0	70	30	0	0	0	0	0	0	0	0
22	2439	0	70	30	0	0	0	0	0	0	0	0
23	2439.5	0	70	30	0	0	0	0	0	0	0	0
24	2440	0	95	0	5	0	0	0	0	0	0	0
25	2440.5	0	95	0	5	0	0	0	0	0	0	0

Description

A dataset containing the prices and other attributes of a sample of 3000 diamonds. The variables are as follows:

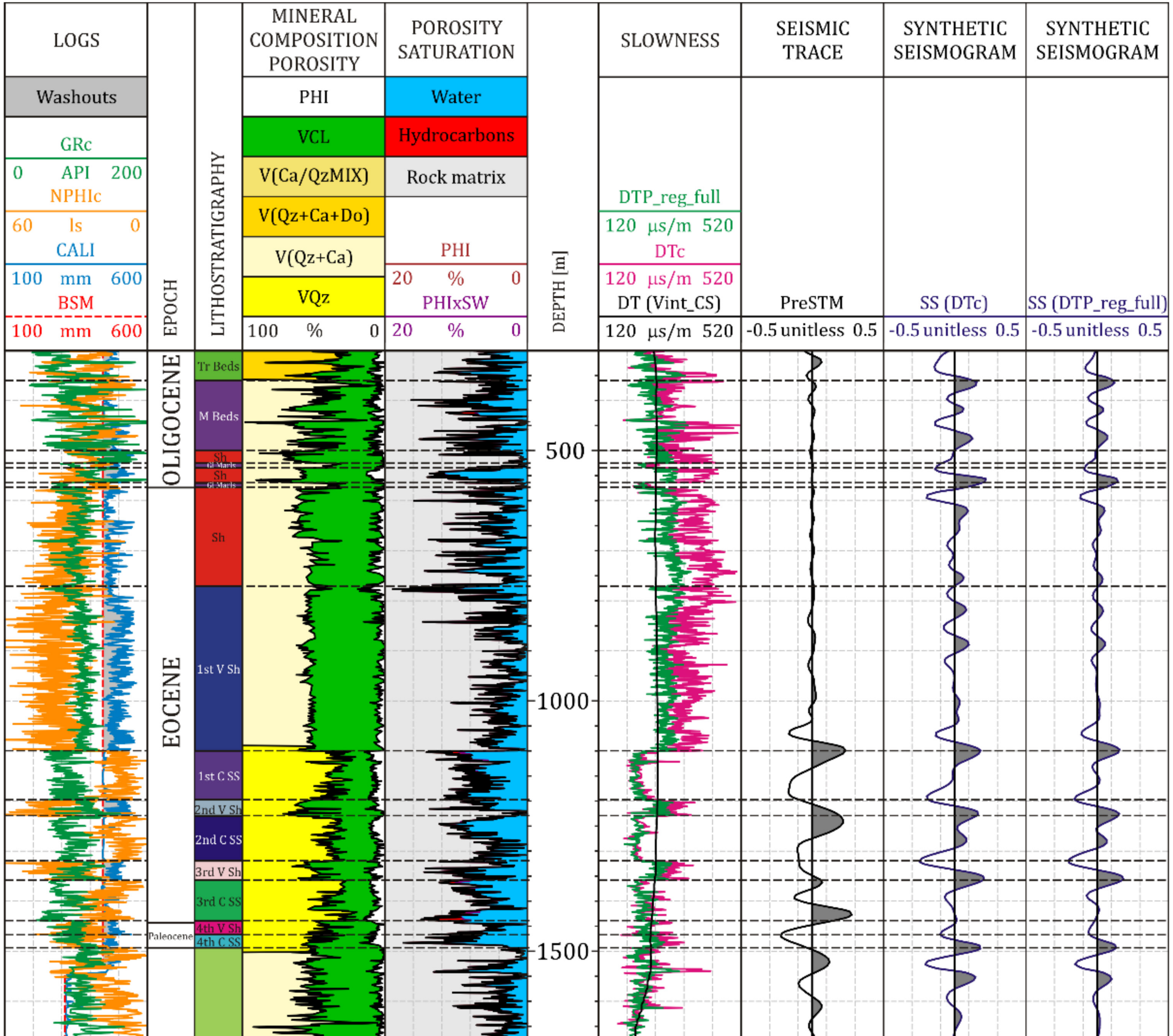
Variables

- price = price in US dollars ($338–$18,791)
- carat = weight of the diamond (0.2–3.00)
- clarity = a measurement of how clear the diamond is (I1 (worst), SI2, SI1, VS2, VS1, VVS2, VVS1, IF (best))
- cut = quality of the cut (Fair, Good, Very Good, Premium, Ideal)
- color = diamond color, from J (worst) to D (best)
- depth = total depth percentage = z / mean(x, y) = 2 * z / (x + y) (54.2–70.80)
- table = width of top of diamond relative to widest point (50–69)
- x = length in mm (3.73–9.42)
- y = width in mm (3.71–9.29)
- z = depth in mm (2.33–5.58)
- date = shipment date



Additional information

Diamond search engine



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Part 2:

SYNTHETIC DTC

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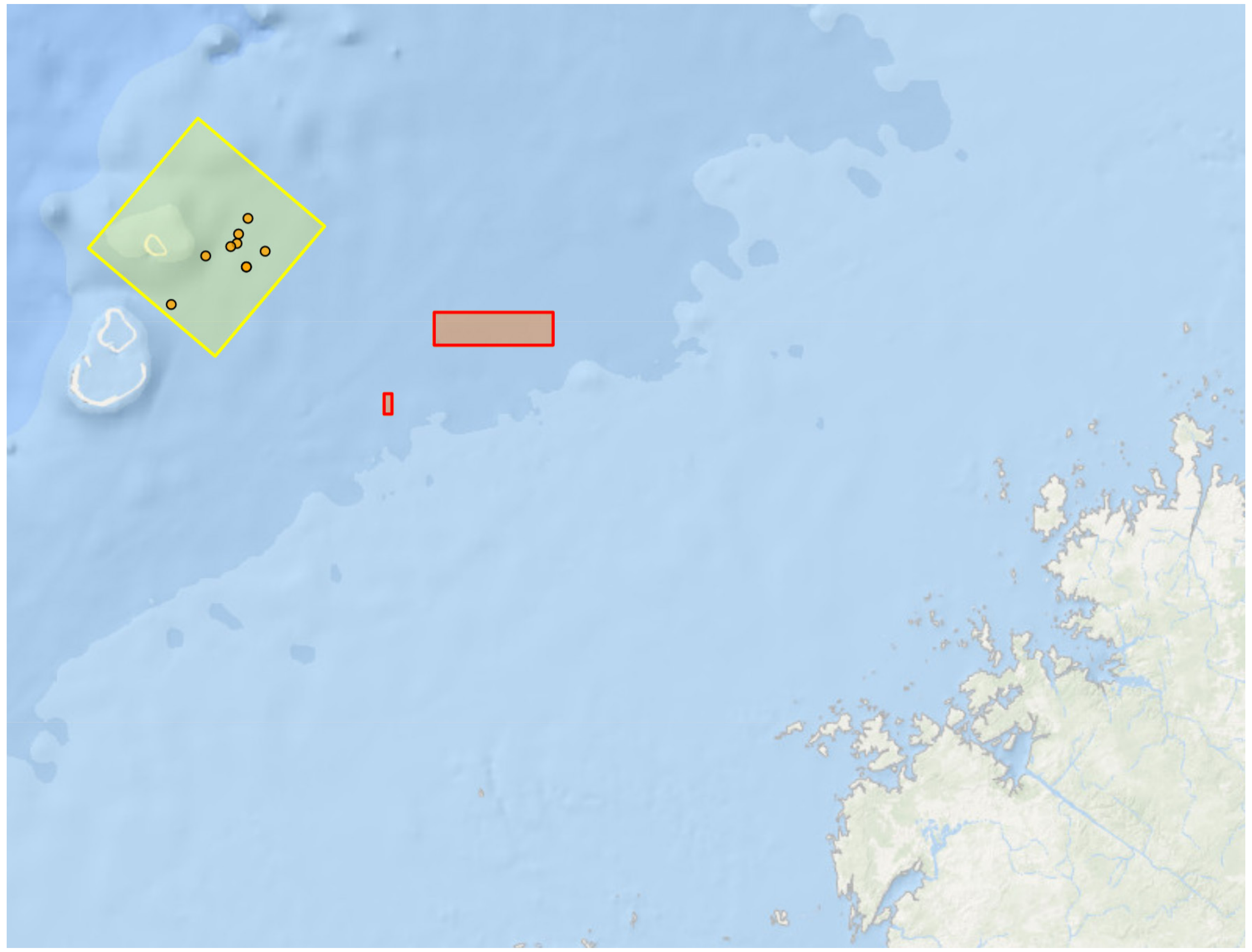
Synthetic DTC

- Poseidon 3D (Australia)
- Mud-logging from well *Poseidon-2*
- Chip descriptions + GR + RDEP (LWD)
- De-trend logs
- Standardize the data (Z-Score)
- Predict DTC
    - Linear regression
    - Step-wise regression
    - XGBoost



Synthetic DTC: LWD

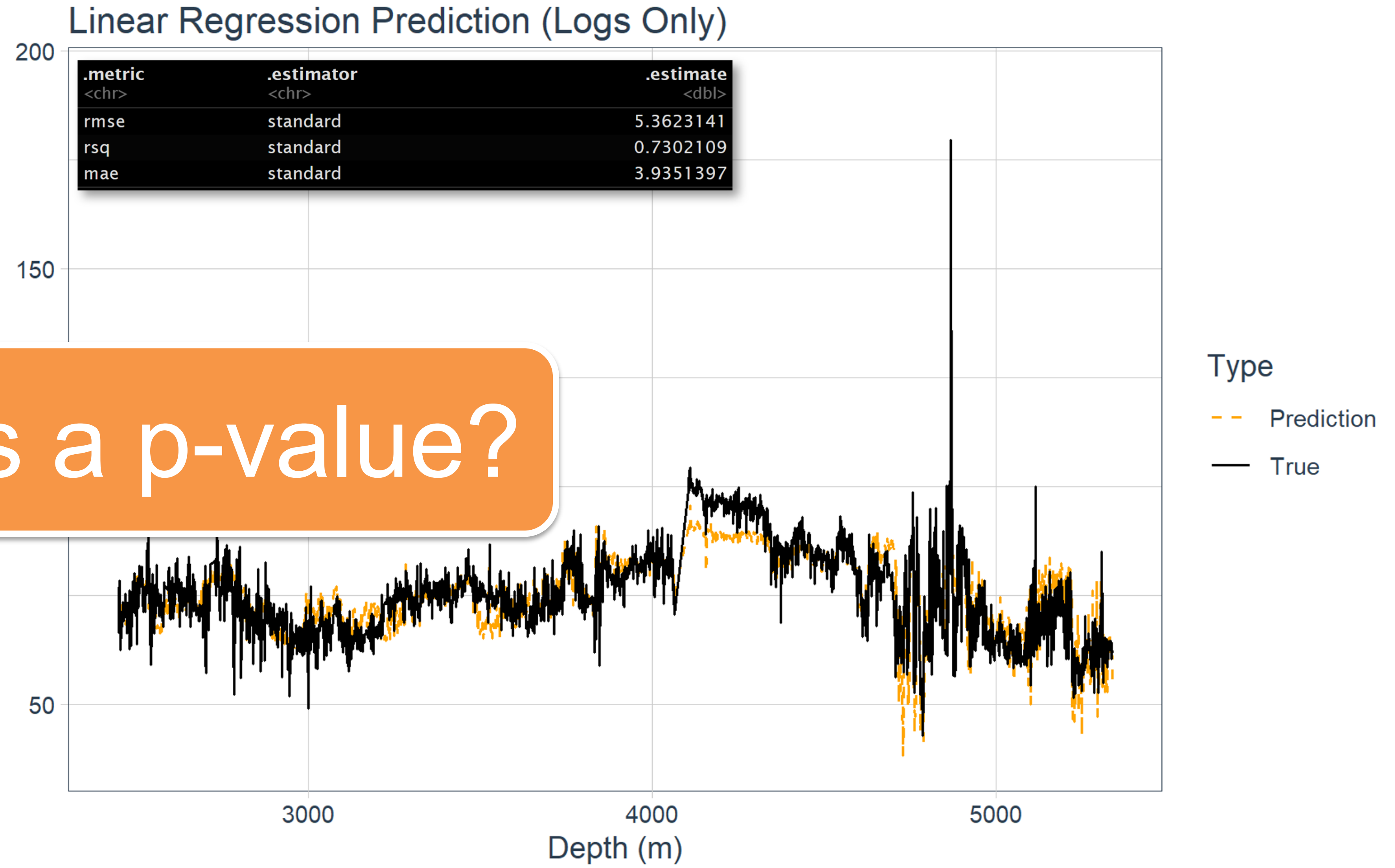
40/60 data split

```
Call:
lm(formula = DTC_Detrended ~ GR + RDEP + `Depth (m)`, data = train)

Residuals:
    Min      1Q  Median      3Q     Max
-27.379  -3.160  -0.161   3.037  33.115

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.11421    0.11001  -1.038    0.299
GR           1.91385    0.12934  14.797   <2e-16 **
RDEP        -7.62717    0.12629 -60.395   <2e-16 **
`Depth (m)` -0.07992    0.10949  -0.730    0.466
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 5.244 on 2269 degrees of freedom
Multiple R-squared:  0.7318,    Adjusted R-squared:  0.7315
F-statistic:  2064 on 3 and 2269 DF,  p-value: < 2.2e-16
```

What is a p-value?

Not statistically significant

Significance level: 0.05



$R^2 = 0.73$

Hypothesis Testing

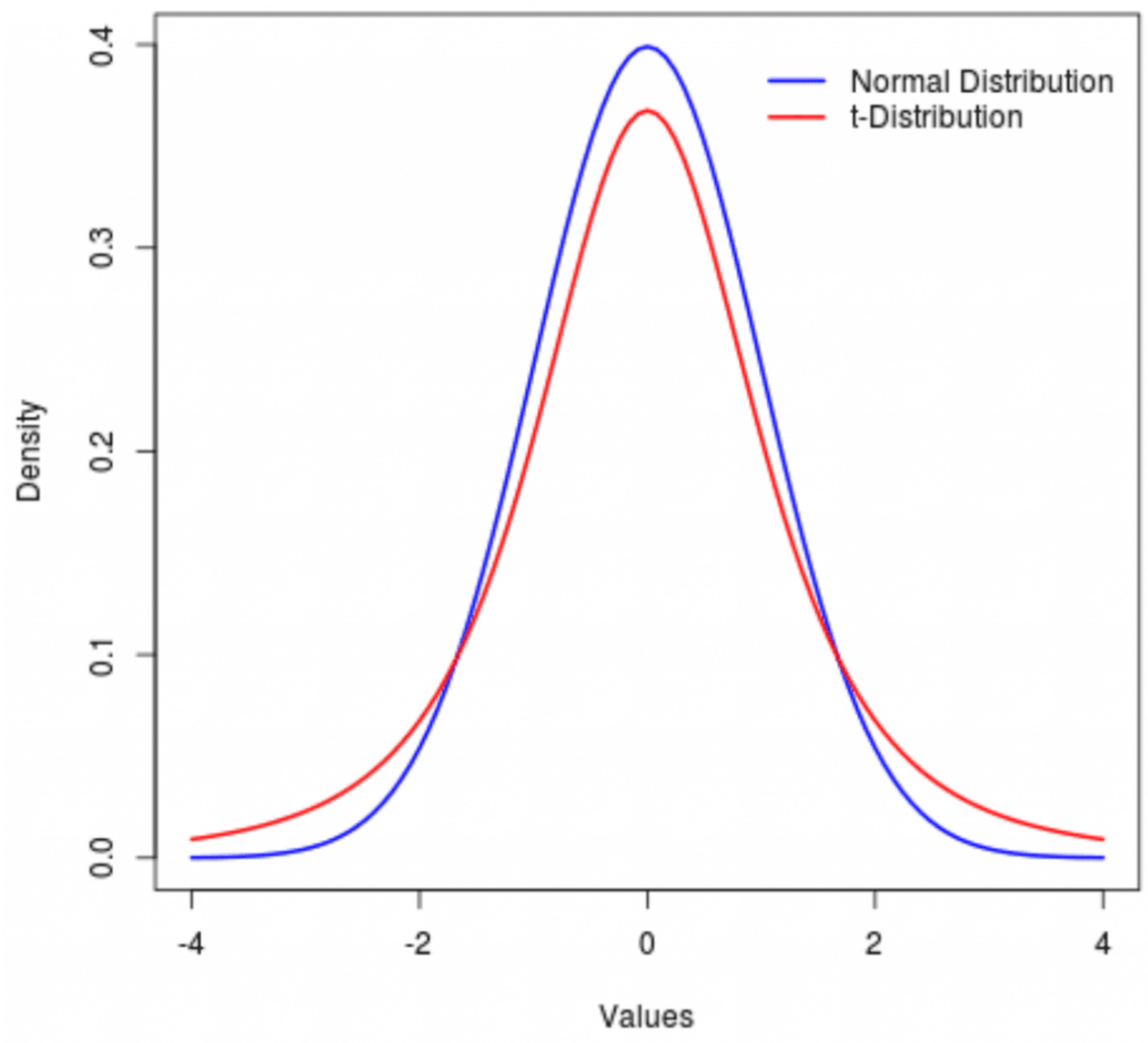
Null hypothesis → H_0: $w = 0$
Alternate hypothesis → H_a: $w \neq 0$

P-value (or *probability value*) is the probability of the Null Hypothesis being true.

The p-value is determined from a statistical value of the population distribution.

But what is the population distribution?

Hypothesis Testing



Significance level: 0.05

- t distribution
- Used when:
  - Small amount of data
  - Population's standard deviation is unknown
- t-statistic

$$t = \frac{w - w_0}{se(w)}$$

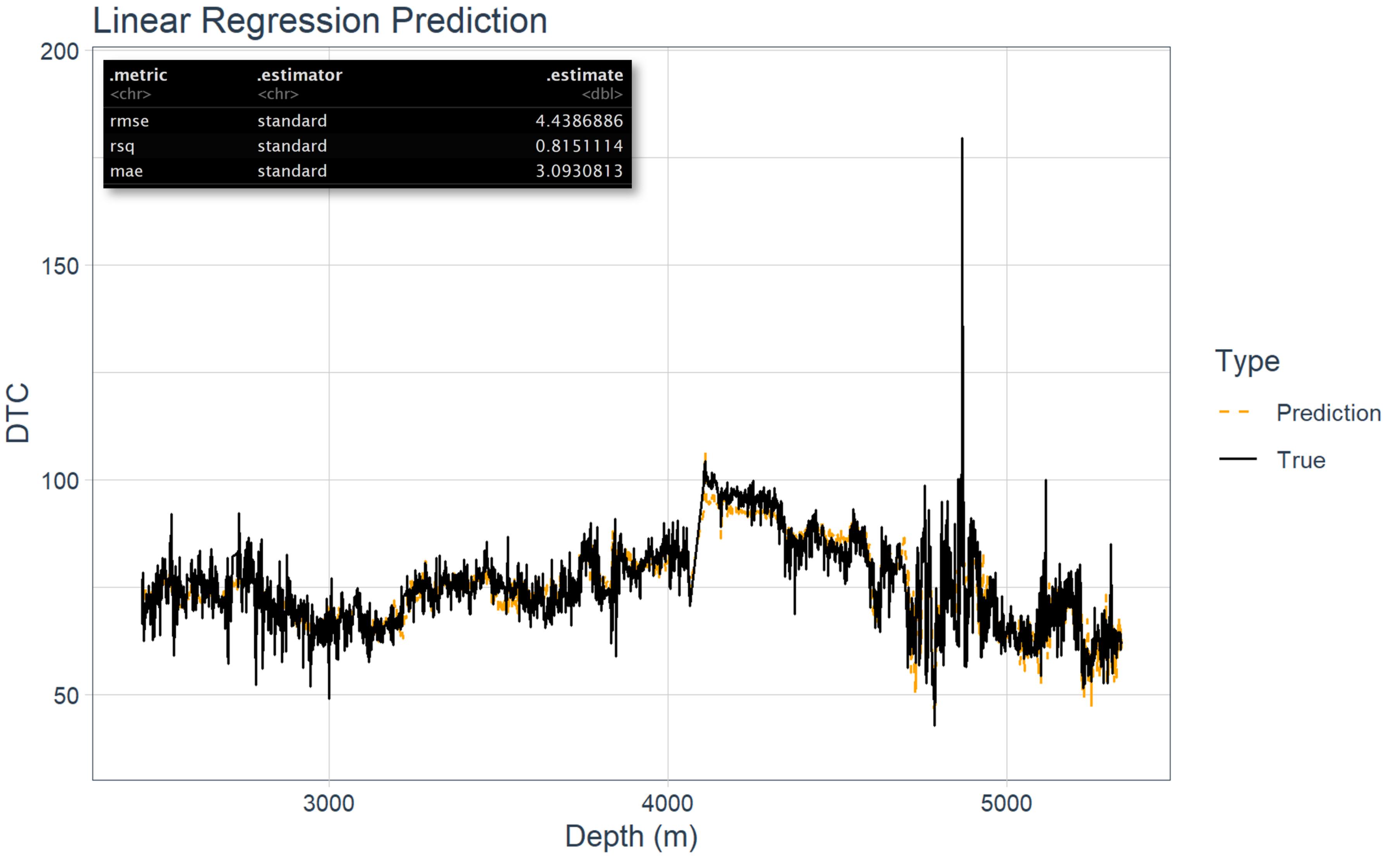
Where:

- *w* is the estimated weight
- w_0 is the hypothesis weight (equals zero)
- se(w) is the standard error of the weight

Synthetic DTC: LWD + Chip Descriptions

40/60 data split

```
Call:
lm(formula = DTC_Detrended ~ . - Depth - Trend_DTC - DTC, data = train)

Residuals:
     Min       1Q   Median       3Q      Max
-24.2906  -2.3174  -0.0601   2.4379  22.1395

Coefficients:
                                       Estimate Std. Error t value Pr(>|t|)
(Intercept)                            -0.07621    0.09041  -0.843 0.399360
`Depth (m)`                            -5.10753    0.43234 -11.814  < 2e-16 ***
`Argillaceous Calcilutite`             -0.28764    0.42570  -0.676 0.499306
Calcarenite                            -2.53034    0.75655  -3.345 0.000838 ***
Cement                                  0.34663    0.08092   4.284 1.92e-05 ***
Calcilutite                             0.06983    0.44667   0.156 0.875787
`Calcarenite Calcilutite`              -0.47073    0.14862  -3.167 0.001560 **
Chert                                  -0.44993    0.16017  -2.809 0.005010 **
`Calcarenite Chert`                    -0.40398    0.15794  -2.558 0.010602 *
`Calcilutite Argillaceous Calcarenite`  0.05612    0.14630   0.384 0.701306
`Argillaceous Calcarenite`             -0.27558    0.12137  -2.271 0.023270 *
`Argillaceous Calcisiltite`            -0.12594    0.08487  -1.484 0.137975
`Calcilutite 1`                         0.19880    0.11180   1.778 0.075495 .
`Calcareous Siltstone`                 -0.13957    0.09888  -1.412 0.158227
`Argillaceous Calcilutite 1`            0.34530    0.09703   3.559 0.000381 ***
Marl                                    0.68583    0.26453   2.593 0.009587 **
Sandstone                               0.24984    0.27965   0.893 0.371752
`Marl Calcilutite`                      0.12855    0.13569   0.947 0.343524
`Calcareous Claystone`                  0.08277    0.35293   0.235 0.814598
Claystone                               2.97673    0.60937   4.885 1.11e-06 ***
`Claystone 1`                           0.20035    0.17072   1.174 0.240709
Contamination                           0.29400    0.11964   2.457 0.014075 *
Siltstone                              -0.24599    0.51090  -0.481 0.630218
Volcanic                                0.38974    0.12842   3.035 0.002434 **
`No Lithology`                          0.30034    0.13603   2.208 0.027349 *
`Ferruginous Volcanic`                  1.10406    0.20897   5.283 1.39e-07 ***
`Argillaceous Volcanic`                 0.30196    0.30407   0.993 0.320785
`Siltstone 1`                           0.08152    0.11029   0.739 0.459887
`Siltstone  Siltstone 1`                0.14090    0.06590   2.138 0.032627 *
`Argillaceous Siltstone`                0.31283    0.13287   2.354 0.018638 *
`Ca (%)`                               -1.68043    0.67561  -2.487 0.012945 *
GR                                      2.27713    0.13907  16.374  < 2e-16 ***
RDEP                                   -4.72598    0.15345 -30.799  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.281 on 2240 degrees of freedom
Multiple R-squared:  0.8235,	Adjusted R-squared:  0.821
F-statistic: 326.7 on 32 and 2240 DF,  p-value: < 2.2e-16
```



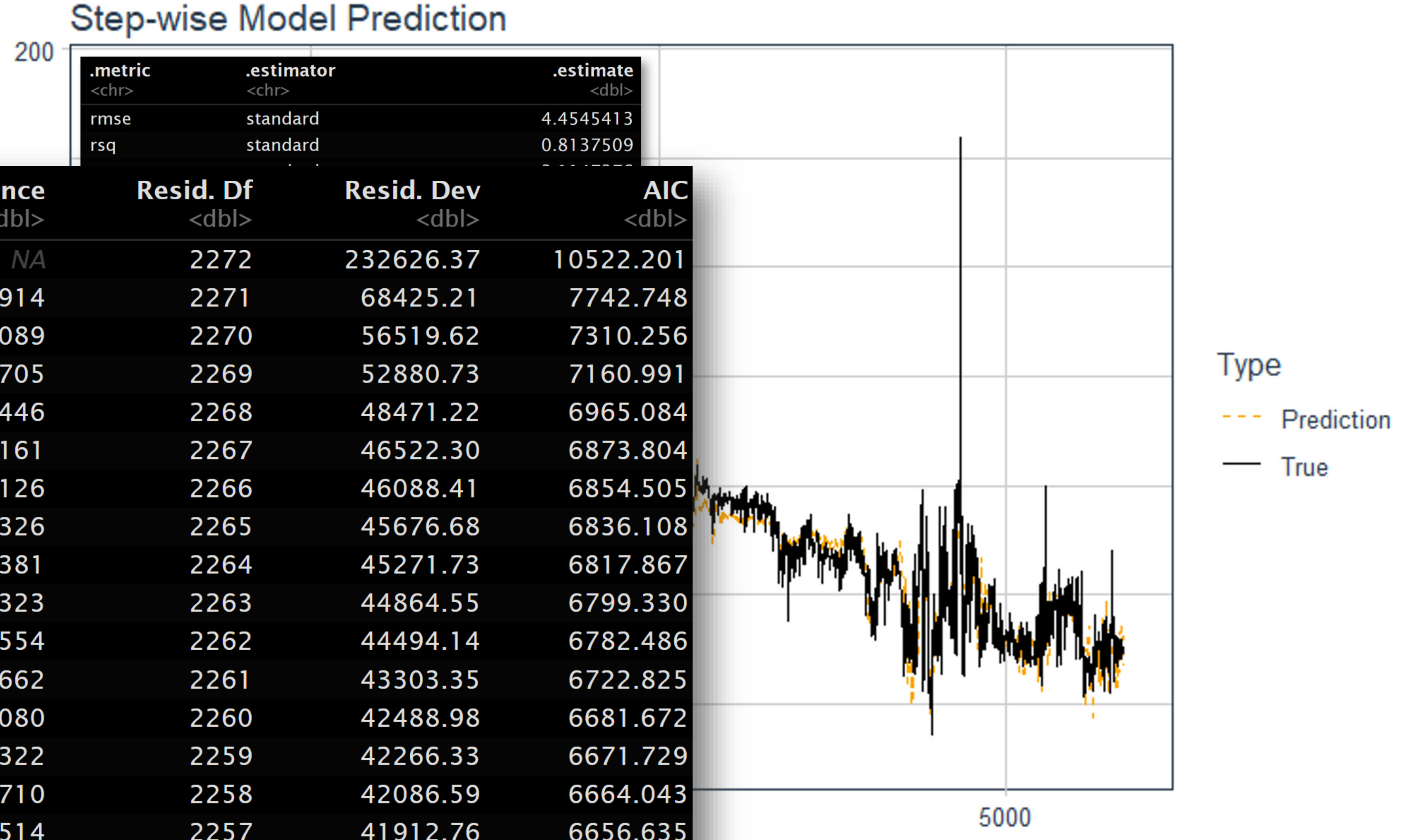
$R^2 = 0.82$

Synthetic DTC: Step-wise regression

40/60 data split

```
Call:
lm(formula = DTC_Detrended ~ RDEP + Claystone + GR + Siltstone +
    Chert + Calcilutite + Marl + Cement + `Ferruginous Volcanic` +
    `Depth (m)` + `Ca (%)` + Calcarenite + `Argillaceous Calcilutite 1` +
    Volcanic + `Calcarenite Calcilutite` + Contamination + `Calcarenite Chert` +
    `No Lithology` + `Argillaceous Ca
    `Siltstone  Siltstone 1` + `Calci
    data = train)

Residuals:
     Min       1Q   Median       3Q
-23.7128  -2.3492  -0.0624   2.4954

Coefficients:
                              Estimate
(Intercept)                   -0.06767
RDEP                          -4.63892
Claystone                      2.64004
GR                             2.26257
Siltstone                     -0.61817
Chert                         -0.35745
Calcilutite                    0.29630
Marl                           0.73528
Cement                         0.35096
`Ferruginous Volcanic`         1.05934
`Depth (m)`                   -4.89432
`Ca (%)`                      -2.69692
Calcarenite                   -1.87118
`Argillaceous Calcilutite 1`   0.28086
Volcanic                       0.31937
`Calcarenite Calcilutite`     -0.36713
Contamination                  0.23988
`Calcarenite Chert`           -0.30700
`No Lithology`                 0.23056
`Argillaceous Calcarenite`    -0.23653
`Argillaceous Siltstone`       0.25202
`Siltstone  Siltstone 1`       0.13833
`Calcilutite 1`                0.21857
`Argillaceous Calcisiltite`   -0.12187
---
Signif. codes:  0 '***' 0.001 '**' 0.

Residual standard error: 4.281 on 224
Multiple R-squared:  0.8229,    Adjus
F-statistic: 454.2 on 23 and 2249 DF,
```

Step <S3: AsIs>	Df <dbl>	Deviance <dbl>	Resid. Df <dbl>	Resid. Dev <dbl>	AIC <dbl>
	NA	NA	2272	232626.37	10522.201
+ RDEP	-1	164201.15914	2271	68425.21	7742.748
+ Claystone	-1	11905.59089	2270	56519.62	7310.256
+ GR	-1	3638.88705	2269	52880.73	7160.991
+ Siltstone	-1	4409.50446	2268	48471.22	6965.084
+ Chert	-1	1948.92161	2267	46522.30	6873.804
+ Calcilutite	-1	433.89126	2266	46088.41	6854.505
+ Marl	-1	411.73326	2265	45676.68	6836.108
+ Cement	-1	404.94381	2264	45271.73	6817.867
+ `Ferruginous Volcanic`	-1	407.18323	2263	44864.55	6799.330
+ `Depth (m)`	-1	370.41554	2262	44494.14	6782.486
+ `Ca (%)`	-1	1190.78662	2261	43303.35	6722.825
+ Calcarenite	-1	814.37080	2260	42488.98	6681.672
+ `Argillaceous Calcilutite 1`	-1	222.65322	2259	42266.33	6671.729
+ Volcanic	-1	179.73710	2258	42086.59	6664.043
+ `Calcarenite Calcilutite`	-1	173.82514	2257	41912.76	6656.635
+ Contamination	-1	107.77090	2256	41804.99	6652.783
+ `Calcarenite Chert`	-1	110.49629	2255	41694.50	6648.767
+ `No Lithology`	-1	99.43980	2254	41595.06	6645.340
+ `Argillaceous Calcarenite`	-1	96.34674	2253	41498.71	6642.069
+ `Argillaceous Siltstone`	-1	82.81256	2252	41415.90	6639.529
+ `Siltstone Siltstone 1`	-1	85.12202	2251	41330.77	6636.852
+ `Calcilutite 1`	-1	82.97880	2250	41247.80	6634.284
+ `Argillaceous Calcisiltite`	-1	39.81617	2249	41207.98	6634.089

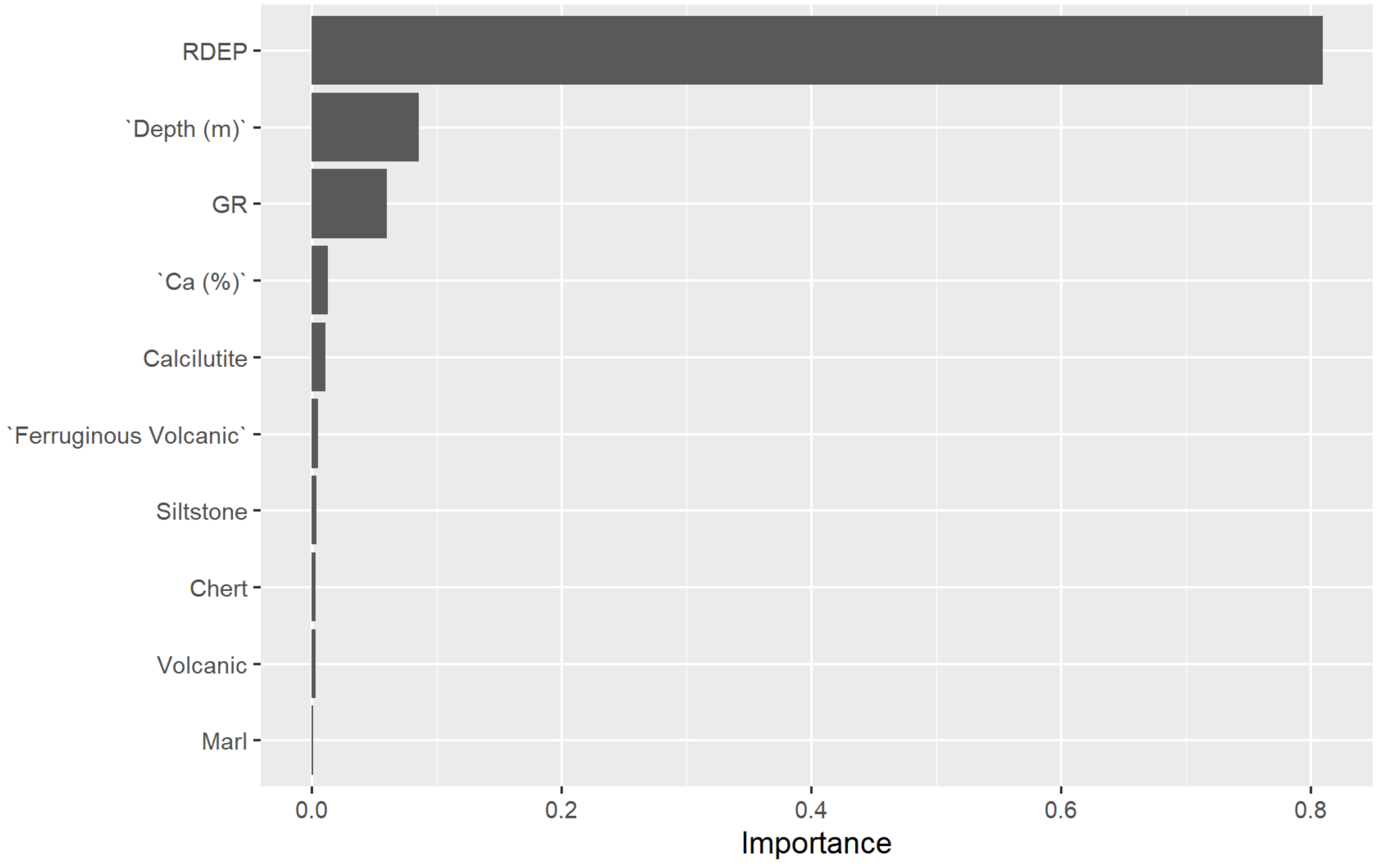


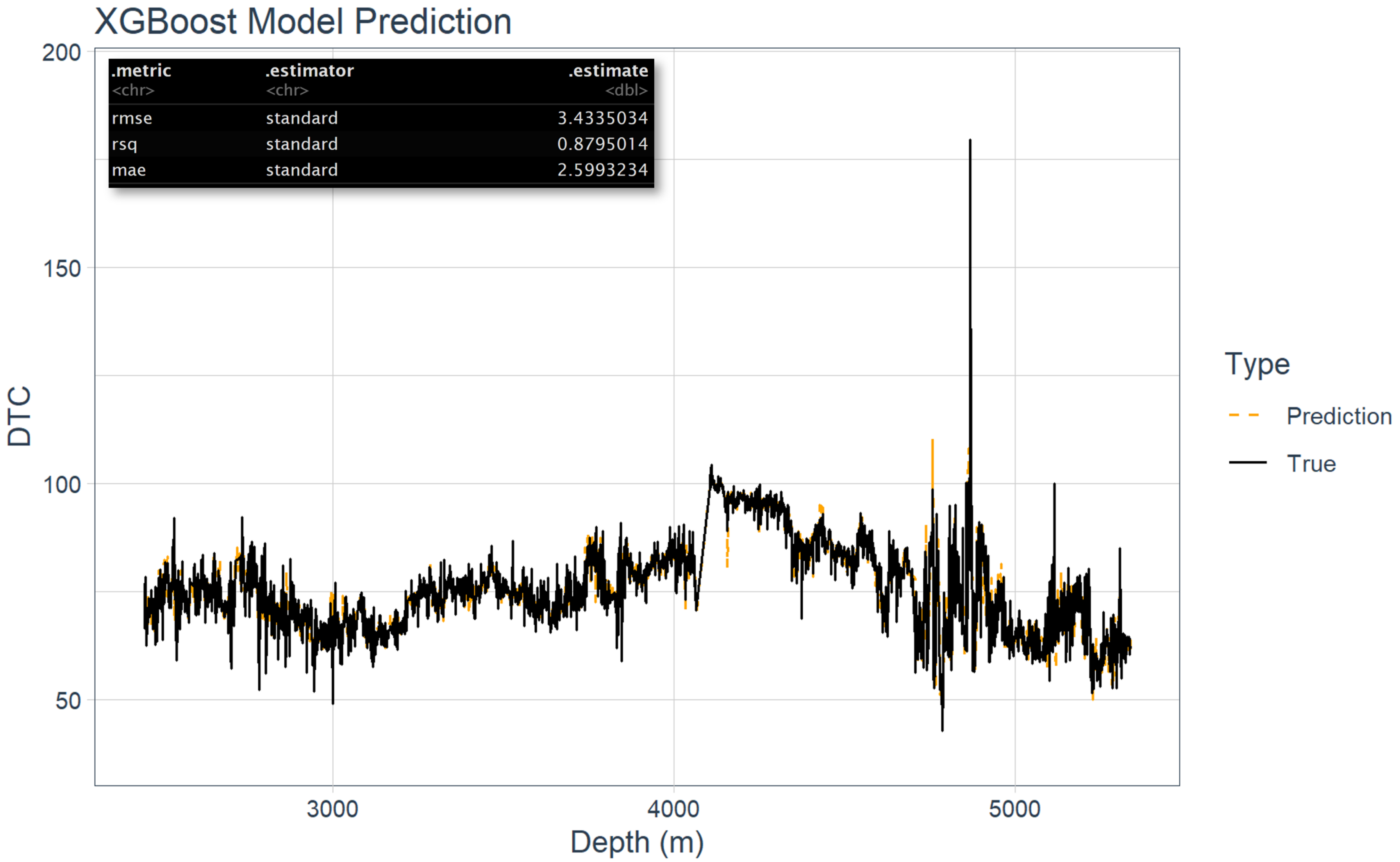
AIC = Akaike Information Criterion

Evaluate the relative quality of models.

Synthetic DTC: XGBoost

40/60 data split

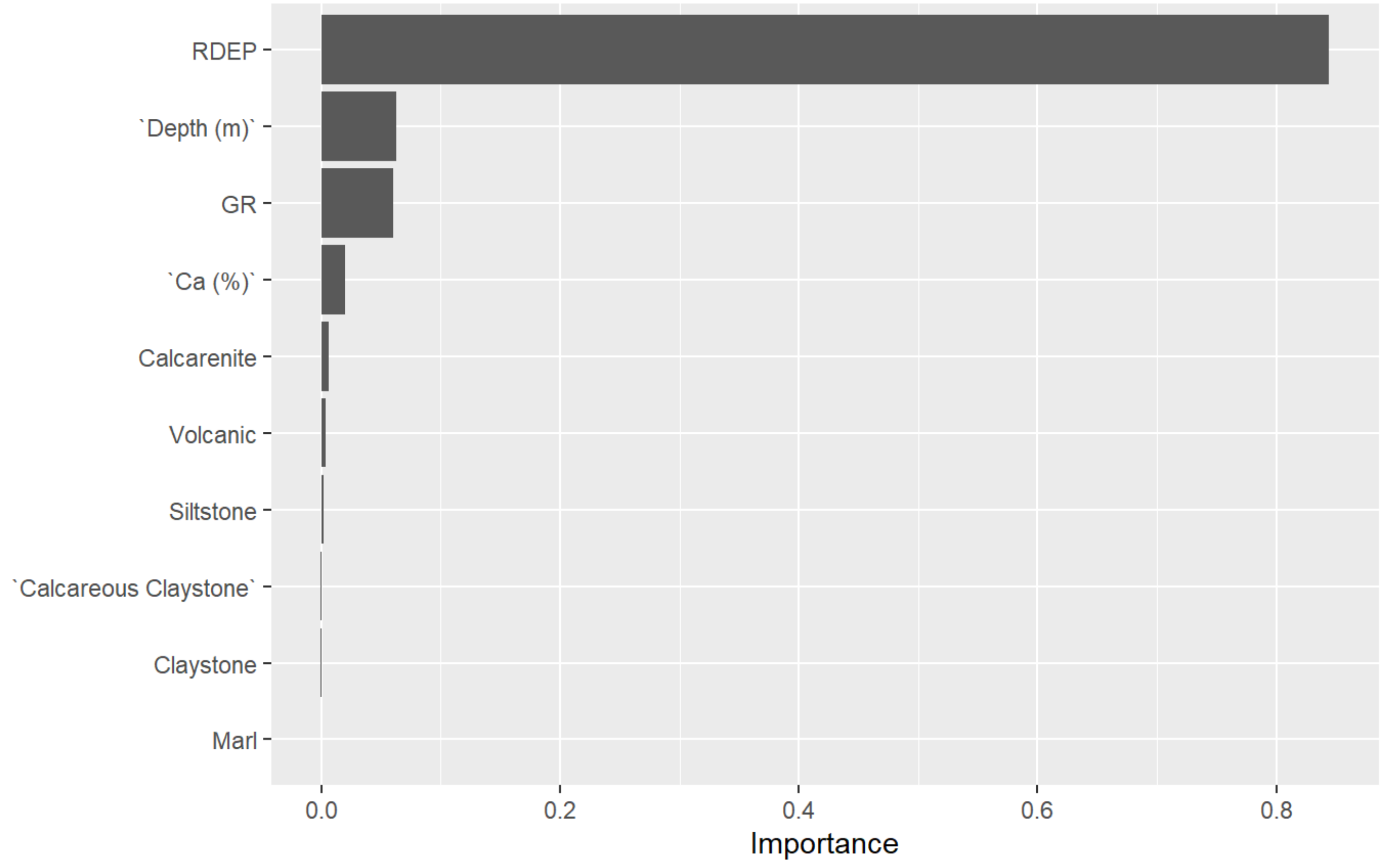


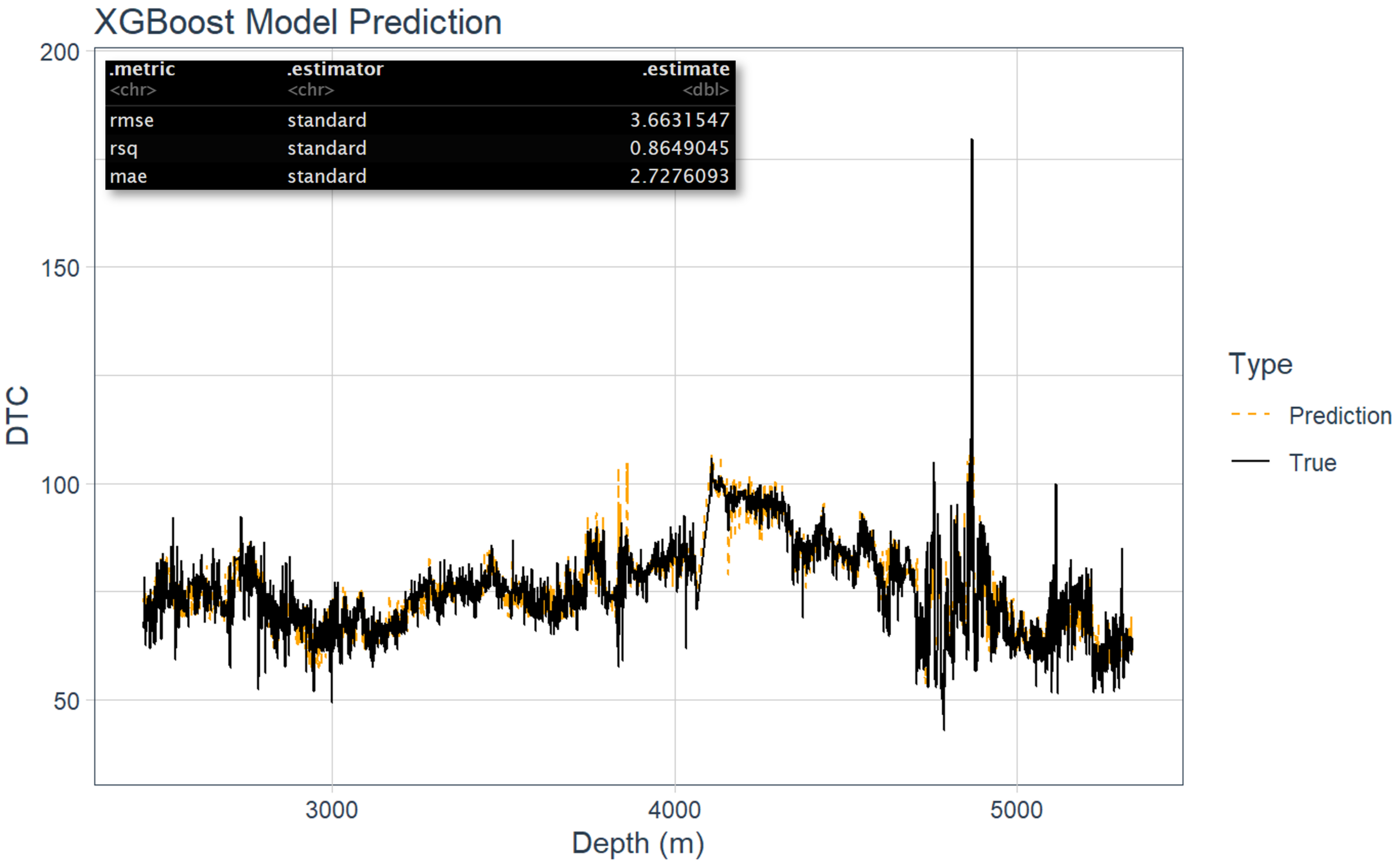


$R^2 = 0.88$

Synthetic DTC: XGBoost

5/95 data split





R^2 = 0.86

Part 3:

CONCLUSIONS

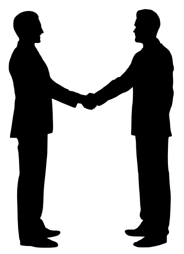
Conclusions

PDF to Table

- Mud-logging chip descriptions
- Complex tables in PDF
- Successfully converted to CSV tables
- Redo processes to other templates
- Build the app

Synthetic DTC

- Chip descriptions improve DTC predictions
- Step-wise regression selected statistically significant features
- XGBoost relies on LWD/Wireline logs to predict DTC
- All models were robust



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CREWES DSI

Thank You!

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