Ancient Micro Debitage

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Executive Summary

Objective (main):

Determine what ML models are best for classifying lithic vs. non-lithic data

Approach:

- K-Means was used to annotate “unlabeled” data
- Data was split into training, test sets (hold out set for validation)
- Lazy Predict was used to run all models to determine baseline performance on test data
- Hyperparameters of top-performing models were tuned using GridSearchCV
- Tuned models were re-evaluated on test and holdout sets

Key Findings:

- In general, Random Forest Classifier performs the best → achieved 100% accuracy on test set for experiment 9 data (Hyperparameter tuning improves performance of models for most models)
- LightGBM is the most time-efficient model with relatively good performance

Next steps:

- Train & Test models with more data (more lithic data)
- We can move on to identify the use of different stone tools micro debitage

Data

Soil (Label: 0)

- Archaeological Soil (n = 73313)

Lithic (Label: 1)

Lithic Experimental (n = 5299)

Soil (Label: 0)

- Experiment 9 Sand Gravel 0.125 mm (n = 170885)
- Experiment 9 Sand Gravel 0.25 mm (n = 115876)
- Experiment 9 Sand Gravel 0.5 mm (n = 103144)
- Experiment 9 Sand Gravel 1 mm (n = 10191)
- Experiment 9 Sand Gravel 2 mm (n = 4340)
- Experiment 9 Sand Gravel 4 mm (n = 605)

Go Back

Data

Datasets used (Strategies):

- Lithic Experimental (n = 5299) + Archaeological Soil (n = 73313)
- Lithic Experimental (n = 5299) + All Experiment 9 data (n = 405041)
- Lithic Experimental (n = 5299) + All Soil/Sand/Gravel data (n = 478354)

- Lithic Experimental (n = 5299) + Sand Gravel 0.125 mm (n = 170885)
- Lithic Experimental (n = 5299) + Sand Gravel 0.25 mm (n = 115876)
- Lithic Experimental (n = 5299) + Sand Gravel 0.5 mm (n = 103144)
- Lithic Experimental (n = 5299) + Sand Gravel 1 mm (n = 10191)
- Lithic Experimental (n = 5299) + Sand Gravel 2 & 4 mm (n = 4945)

Data

Target variables:

- Type_micro (lithic/non-lithic): A categorical (binary) variable that indicates whether a sample is lithic or non-lithic
- Size_micro (0.125mm, 0.25mm, 0.5mm, >= 1mm): A categorical (multi-class) variable that indicates the size of a particle

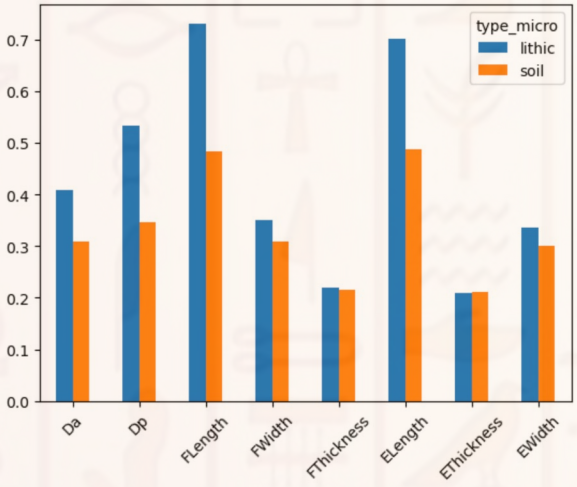
Data Summary:

- Train-Test/Holdout split: 90/10
- Train/Test split: 80/20
- Stratify

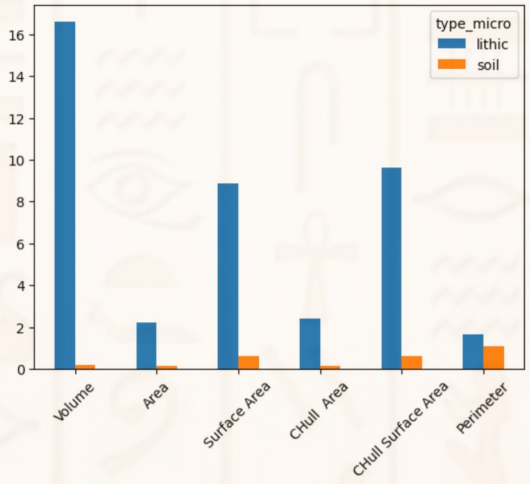
EDA - Compare means (Size)

Variable Description

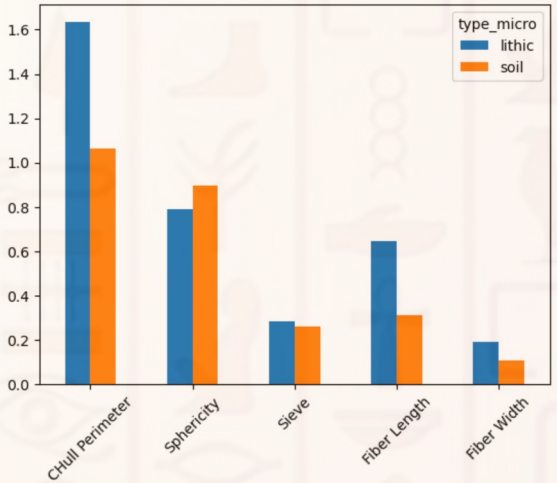
(Size - 1D)



(Size - 2D/3D)

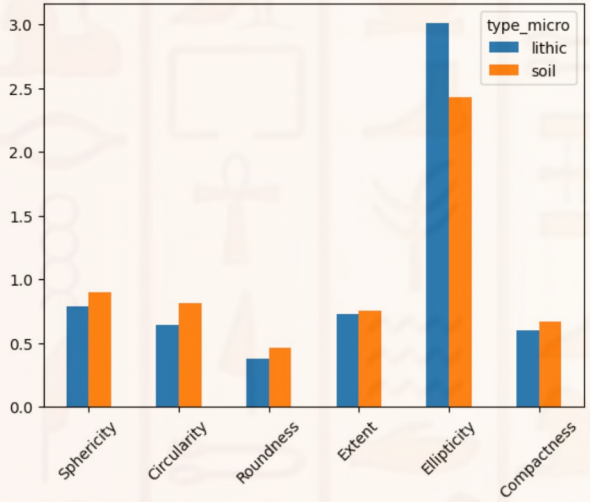


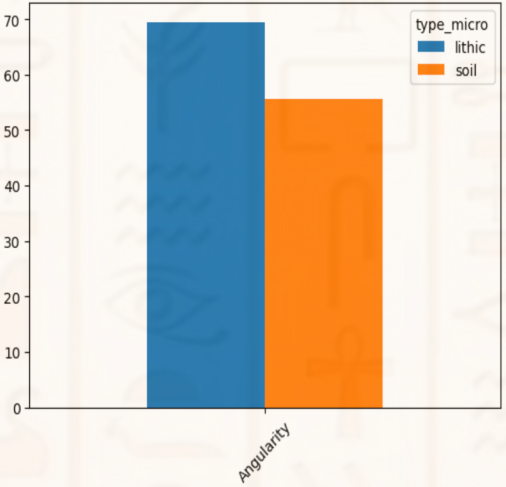
(Size - other)



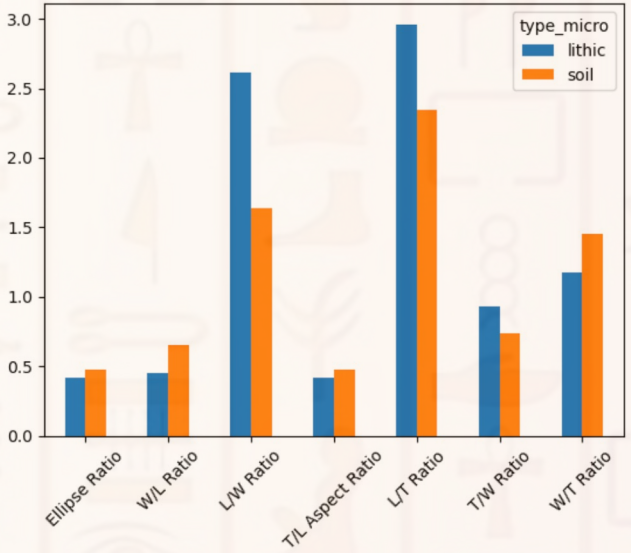
EDA - Compare means (Shape/Form)

(Shape/Form)



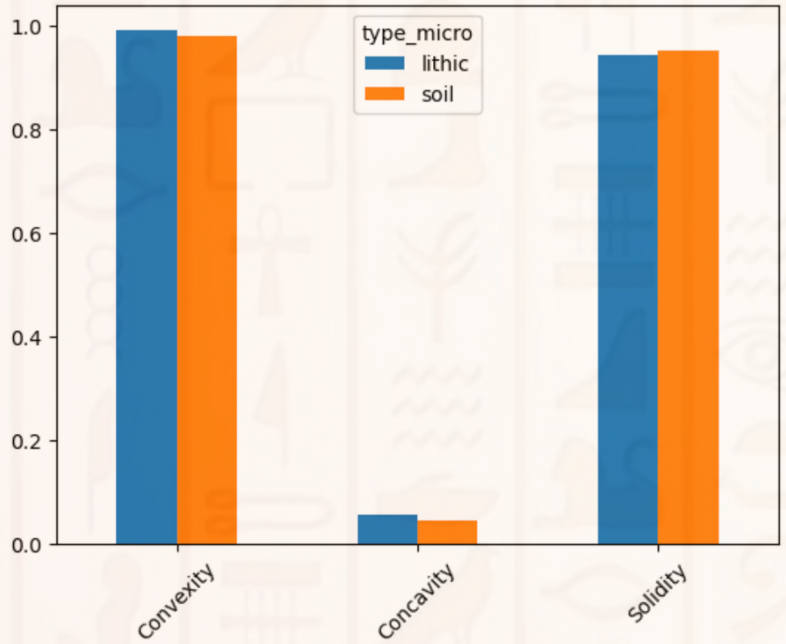


(Ratio)

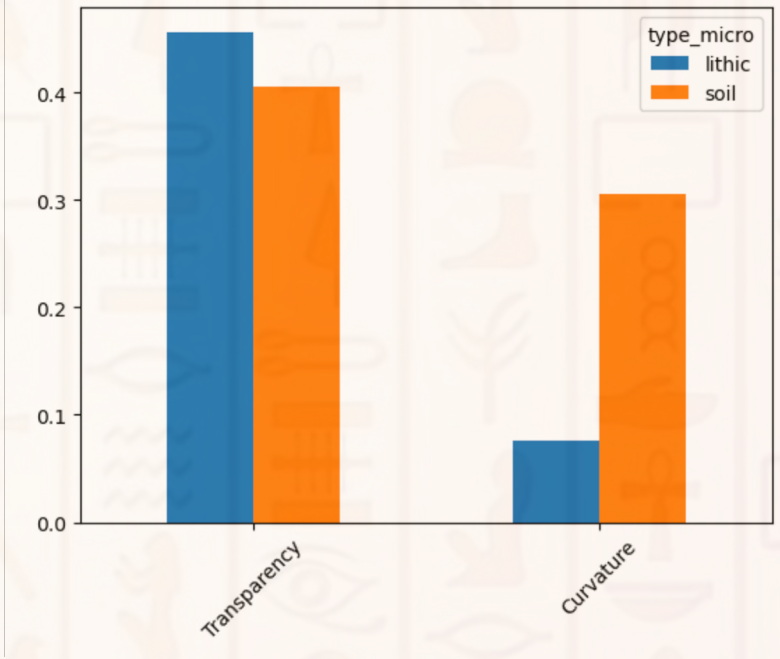


EDA - Compare means (Surface Roughnesses & Intensity)

(Surface Roughness)

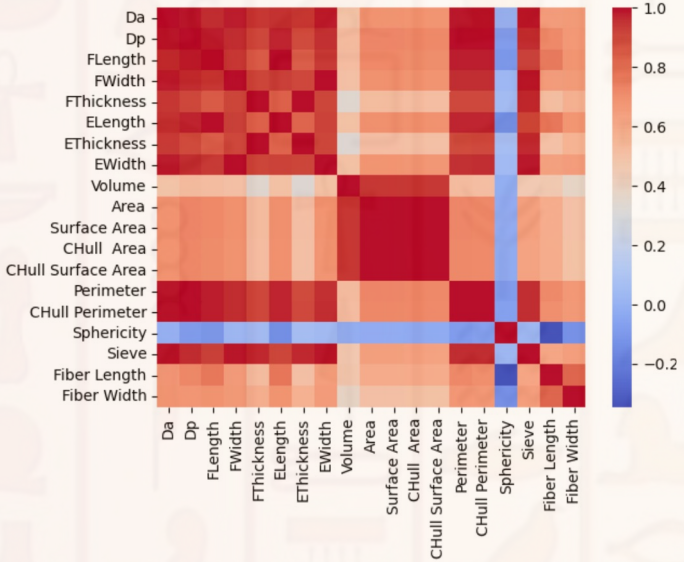


(Intensity)

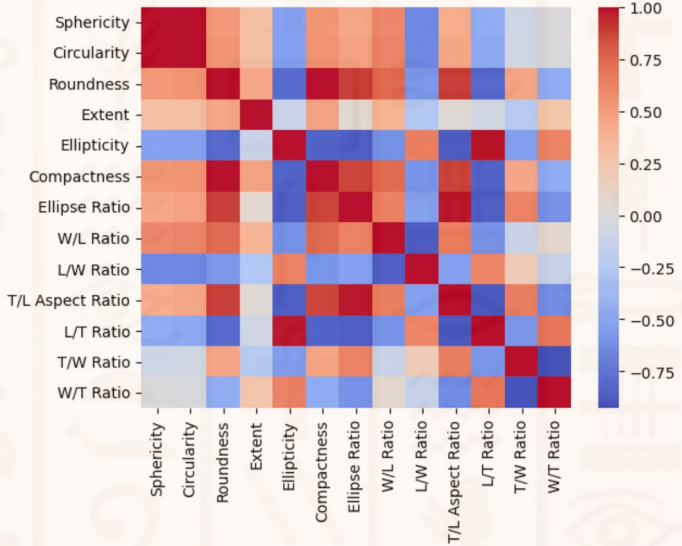


EDA - Correlation matrix (Size)

(Size)



(Shape/form)



(Surface Roughness)

	Convexity	Concavity	Solidity
Convexity	1.00	-0.84	0.84
Concavity	-0.84	1.00	-1.00
Solidity	0.84	-1.00	1.00

(Intensity)

	Transparency	Curvature
Transparency	1.00	0.48
Curvature	0.48	1.00

Data - Processing

Variables to drop

- Filter0, Filter1, Filter2, Filter3, Filter4, Filter5, Filter6 (“Rejected”)
- Hash (0), Id, Imgid
- Krumbein Roundness

Class Imbalance

- Random Undersampling
- Random Oversampling
- SMOTE /& Tomek Links

Missingness

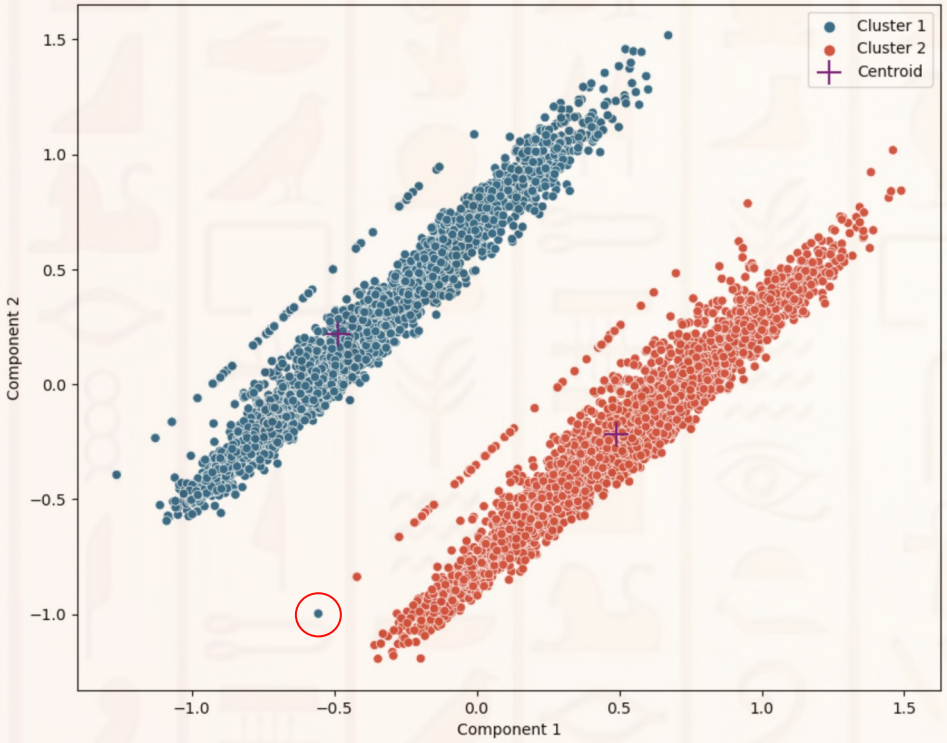
- Krumbein Roundness (not available for soil samples)

Feature engineering & selection

- Type_micro (lithic vs. non-lithic)
- Size_micro (0.125mm, 0.25mm, 0.5mm, 1mm, 2mm, 4mm)
- Standardization (Scaling)
- We used all features

K-Means Clustering with PCA

Discussion



- Data: Random sample of 5299 rows of soil data + 5299 rows of lithic data
- Features used were the top 10 common parameters
- Three principal components
- We achieve good separation between soil and lithic data
- One misclassified point —> there is some lithic mixed in with the soil data

K-means	Binary Classification	Multiclass Classification

Methods & Results - Lazy Predict (all)

Model	Accuracy	Balanced Accuracy	ROC AUC	F1 Score	Time Taken
LGBMClassifier	0.95	0.95	None	0.95	0.28
BaggingClassifier	0.94	0.94	None	0.94	1.09
RandomForestClassifier	0.93	0.93	None	0.93	1.99
SVC	0.92	0.92	None	0.92	1.60
DecisionTreeClassifier	0.92	0.92	None	0.92	0.21
ExtraTreesClassifier	0.92	0.92	None	0.92	0.72
AdaBoostClassifier	0.92	0.92	None	0.92	1.36
LabelSpreading	0.91	0.91	None	0.91	5.34
LabelPropagation	0.91	0.91	None	0.91	1.89
KNeighborsClassifier	0.91	0.91	None	0.91	0.43
CalibratedClassifierCV	0.89	0.89	None	0.89	3.17
LinearSVC	0.89	0.89	None	0.89	0.97
LogisticRegression	0.89	0.89	None	0.89	0.16
LinearDiscriminantAnalysis	0.89	0.89	None	0.89	0.15
RidgeClassifier	0.89	0.89	None	0.89	0.11
RidgeClassifierCV	0.89	0.89	None	0.89	0.10
NuSVC	0.88	0.88	None	0.88	4.63
ExtraTreeClassifier	0.88	0.88	None	0.88	0.06
SGDClassifier	0.88	0.88	None	0.88	0.09
Perceptron	0.87	0.87	None	0.87	0.06
PassiveAggressiveClassifier	0.83	0.83	None	0.83	0.07

Methods & Results - Lazy Predict

(experiment 9)

Model	Accuracy	Balanced Accuracy	ROC AUC	F1 Score	Time Taken
AdaBoostClassifier	0.99	0.99	None	0.99	1.24
LGBMClassifier	0.99	0.99	None	0.99	0.39
RandomForestClassifier	0.99	0.99	None	0.99	1.68
ExtraTreesClassifier	0.99	0.99	None	0.99	0.59
SVC	0.98	0.98	None	0.98	0.84
BaggingClassifier	0.98	0.98	None	0.98	0.88
DecisionTreeClassifier	0.97	0.97	None	0.97	0.20
LabelPropagation	0.97	0.97	None	0.97	1.84
LabelSpreading	0.97	0.97	None	0.97	3.15
KNeighborsClassifier	0.97	0.97	None	0.97	0.40
LinearSVC	0.97	0.97	None	0.97	0.47
CalibratedClassifierCV	0.97	0.97	None	0.97	1.67
LogisticRegression	0.96	0.96	None	0.96	0.15
SGDClassifier	0.96	0.96	None	0.96	0.10
Perceptron	0.96	0.96	None	0.96	0.06
LinearDiscriminantAnalysis	0.96	0.96	None	0.96	0.15
RidgeClassifier	0.96	0.96	None	0.96	0.07
RidgeClassifierCV	0.96	0.96	None	0.96	0.09
ExtraTreeClassifier	0.95	0.95	None	0.95	0.05
NuSVC	0.94	0.94	None	0.94	4.21
PassiveAggressiveClassifier	0.93	0.93	None	0.93	0.06

(Archaeological Soil)

Model	Accuracy	Balanced Accuracy	ROC AUC	F1 Score	Time Taken
LGBMClassifier	0.89	0.89	None	0.89	0.55
RandomForestClassifier	0.88	0.88	None	0.88	2.22
BaggingClassifier	0.88	0.88	None	0.88	1.17
ExtraTreesClassifier	0.87	0.87	None	0.87	1.01
SVC	0.87	0.87	None	0.87	3.59
NuSVC	0.86	0.86	None	0.86	5.59
KNeighborsClassifier	0.86	0.86	None	0.86	0.65
LabelSpreading	0.85	0.85	None	0.85	3.26
LabelPropagation	0.85	0.85	None	0.85	2.60
AdaBoostClassifier	0.85	0.85	None	0.85	1.39
LinearSVC	0.85	0.85	None	0.85	1.20
RidgeClassifier	0.85	0.85	None	0.85	0.09
RidgeClassifierCV	0.85	0.85	None	0.85	0.10
CalibratedClassifierCV	0.84	0.84	None	0.84	4.84
LinearDiscriminantAnalysis	0.84	0.84	None	0.84	0.13
DecisionTreeClassifier	0.84	0.84	None	0.84	0.26
LogisticRegression	0.84	0.84	None	0.84	0.16
SGDClassifier	0.83	0.83	None	0.83	0.13
Perceptron	0.83	0.83	None	0.83	0.07
ExtraTreeClassifier	0.82	0.82	None	0.82	0.06
PassiveAggressiveClassifier	0.80	0.80	None	0.80	0.07

Methods & Results - Lazy Predict (Experiment 9)

(experiment 9 - 0.125mm)

Model	Accuracy	Balanced Accuracy	ROC AUC	F1 Score	Time Taken
LGBMClassifier	1.00	1.00	None	1.00	0.22
AdaBoostClassifier	1.00	1.00	None	1.00	1.45
RandomForestClassifier	0.99	0.99	None	0.99	1.70
ExtraTreesClassifier	0.99	0.99	None	0.99	0.55
BaggingClassifier	0.99	0.99	None	0.99	0.90
SVC	0.99	0.99	None	0.99	0.90
DecisionTreeClassifier	0.99	0.99	None	0.99	0.19

(experiment 9 - 0.25mm)

Model	Accuracy	Balanced Accuracy	ROC AUC	F1 Score	Time Taken
AdaBoostClassifier	1.00	1.00	None	1.00	1.33
LGBMClassifier	0.99	0.99	None	0.99	0.22
SVC	0.99	0.99	None	0.99	0.73
RandomForestClassifier	0.99	0.99	None	0.99	1.81
ExtraTreesClassifier	0.99	0.99	None	0.99	0.59
KNeighborsClassifier	0.99	0.99	None	0.99	0.51
BaggingClassifier	0.99	0.99	None	0.99	0.96
DecisionTreeClassifier	0.99	0.99	None	0.99	0.22
LabelPropagation	0.99	0.99	None	0.99	2.12
LabelSpreading	0.99	0.99	None	0.99	3.43

(experiment 9 - 0.5mm)

Model	Accuracy	Balanced Accuracy	ROC AUC	F1 Score	Time Taken
AdaBoostClassifier	1.00	1.00	None	1.00	1.33
LGBMClassifier	0.99	0.99	None	0.99	0.25
RandomForestClassifier	0.99	0.99	None	0.99	1.80
BaggingClassifier	0.99	0.99	None	0.99	0.94
ExtraTreesClassifier	0.99	0.99	None	0.99	0.55
SVC	0.99	0.99	None	0.99	0.78

(experiment 9 - 1mm)

Model	Accuracy	Balanced Accuracy	ROC AUC	F1 Score	Time Taken
LGBMClassifier	0.99	0.99	None	0.99	0.24
AdaBoostClassifier	0.99	0.99	None	0.99	1.38
RandomForestClassifier	0.99	0.99	None	0.99	1.83
BaggingClassifier	0.99	0.99	None	0.99	1.11
ExtraTreesClassifier	0.99	0.99	None	0.99	0.54
DecisionTreeClassifier	0.98	0.98	None	0.98	0.23
SVC	0.98	0.98	None	0.98	0.90
KNeighborsClassifier	0.98	0.98	None	0.98	0.48
LabelSpreading	0.98	0.98	None	0.98	3.74
LabelPropagation	0.98	0.98	None	0.98	2.47

(experiment 9 - 2&4mm)

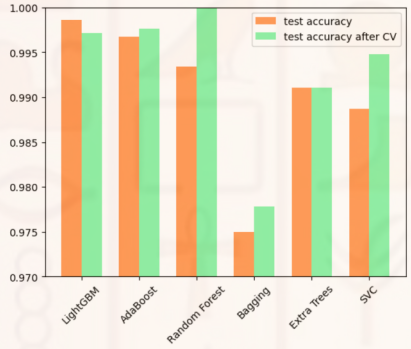
Model	Accuracy	Balanced Accuracy	ROC AUC	F1 Score	Time Taken
LGBMClassifier	1.00	1.00	None	1.00	0.21
AdaBoostClassifier	0.99	0.99	None	0.99	1.40
RandomForestClassifier	0.99	0.99	None	0.99	1.67
ExtraTreesClassifier	0.99	0.99	None	0.99	0.46
BaggingClassifier	0.99	0.99	None	0.99	0.84
SVC	0.99	0.99	None	0.99	0.76
KNeighborsClassifier	0.98	0.98	None	0.98	0.48
DecisionTreeClassifier	0.98	0.98	None	0.98	0.18
LabelPropagation	0.98	0.98	None	0.98	2.29
LabelSpreading	0.98	0.98	None	0.98	3.24

Models

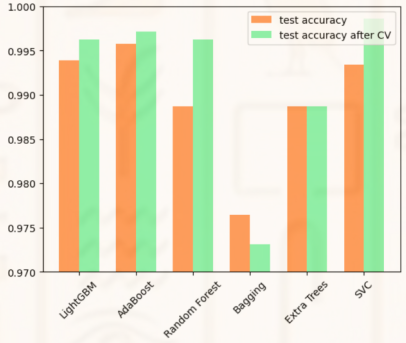
- Light Gradient Boosting Model (LGBM) classifier
- Random Forest Classifier
- Bagging Classifier
- Extra Trees Classifier
- Support Vector Classifier (SVC)
- Adaptive Boosting (AdaBoost) Classifier

Methods & Results - Accuracy (experiment 9)

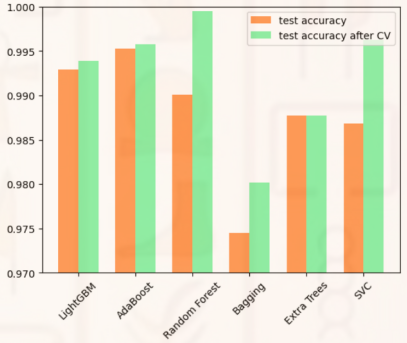
(experiment 9 - 0.125mm)



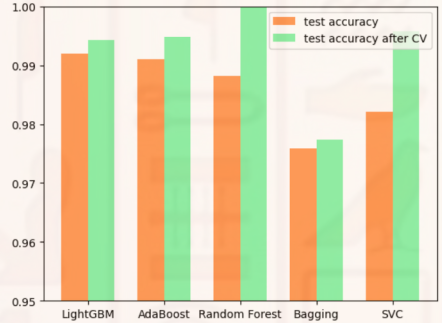
(experiment 9 - 0.25mm)



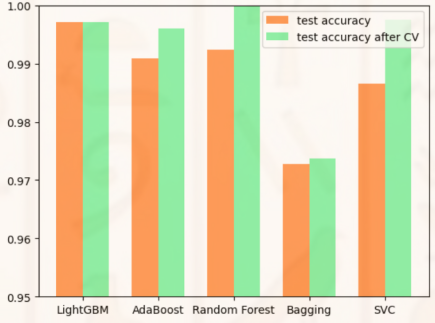
(experiment 9 - 0.5mm)



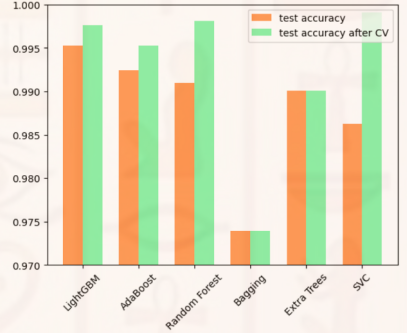
(experiment 9 - 1mm undersampling)



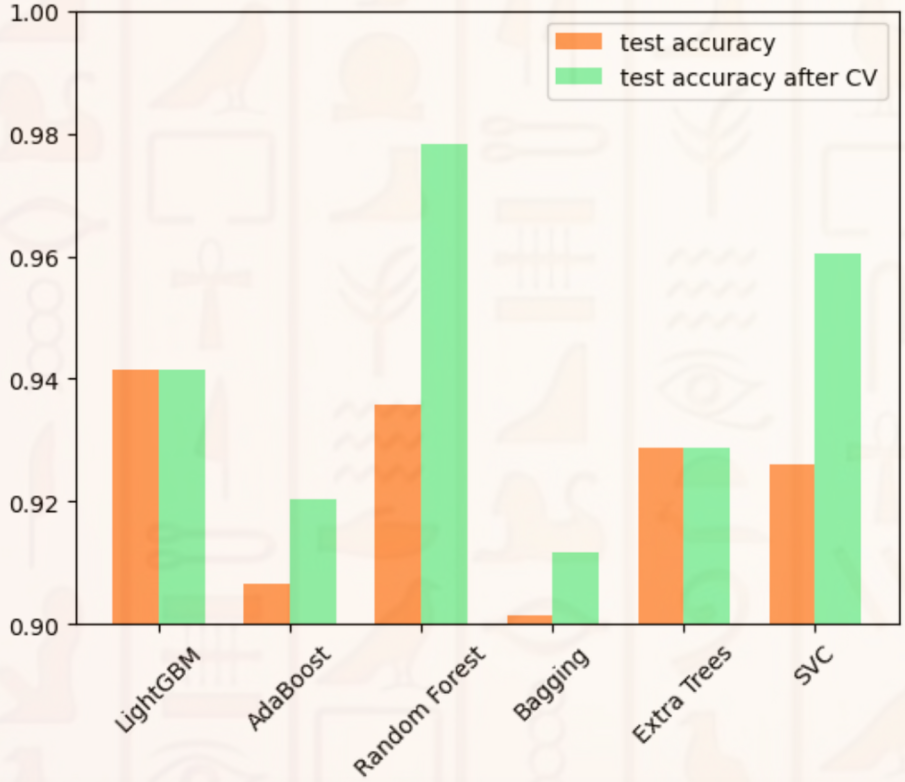
(experiment 9 - 1mm oversampling)



(experiment 9 - 2&4mm)

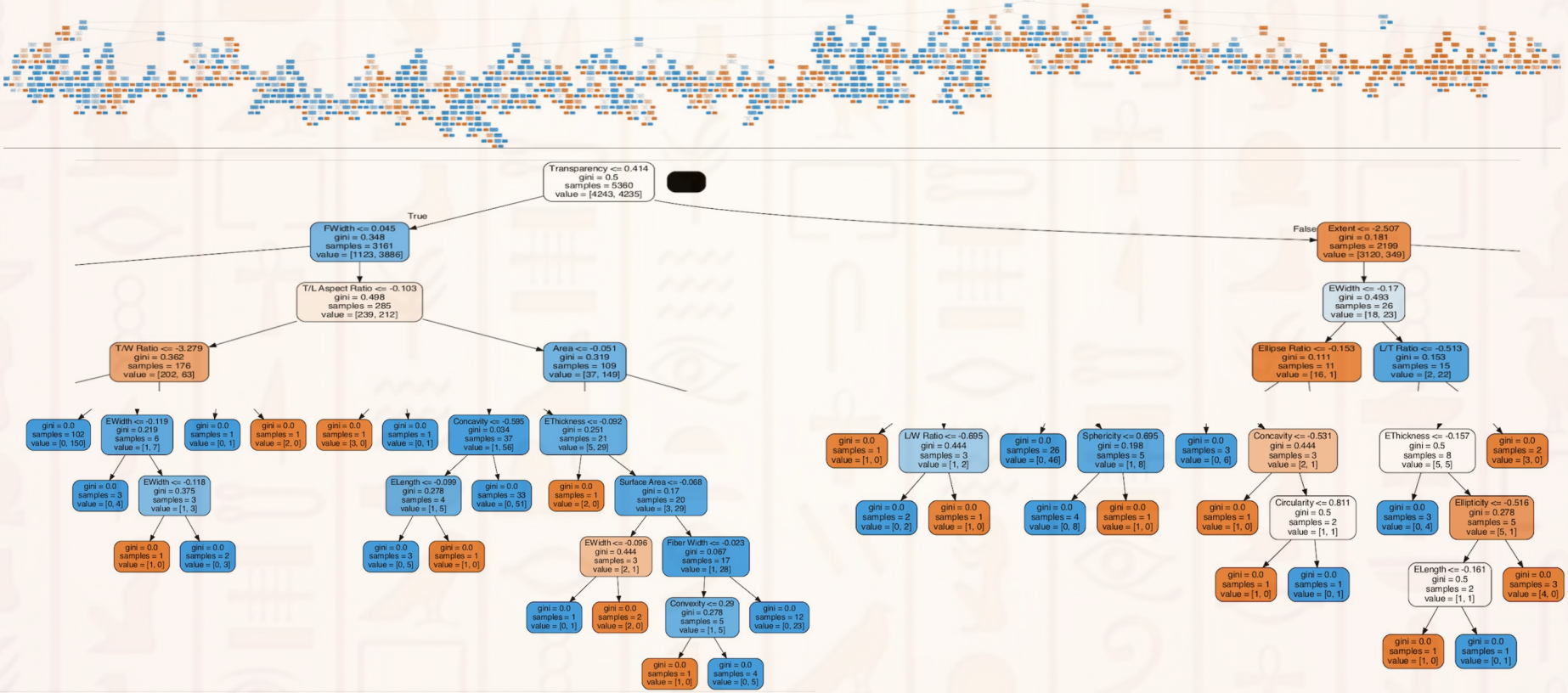


Methods & Results - Accuracy (all)



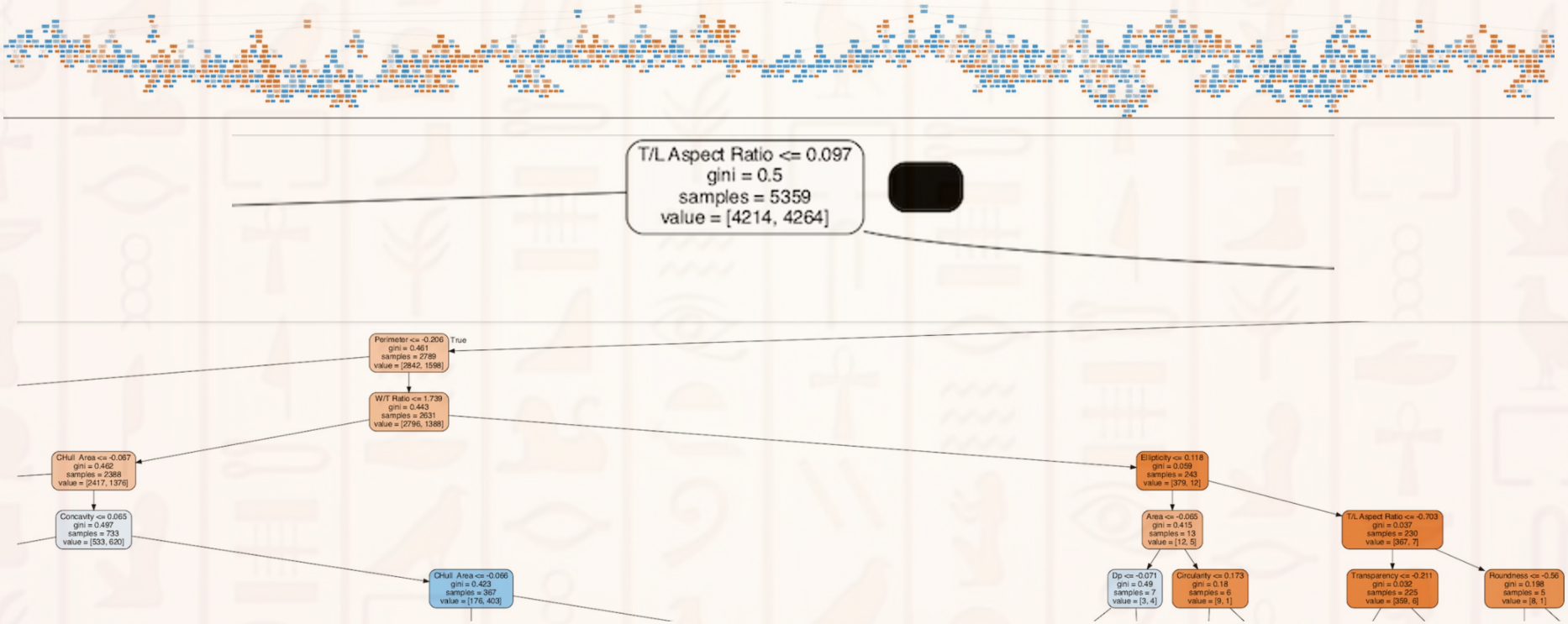
It appears that CV has a much larger effect on Random Forest compared to the other models → significant contributor to RF being the best model

Methods & Results - Plot Trees (ArchaeologicalSoil No.1)



Lazy Predict	Top Performing Models	Feature Importance	Selected Features

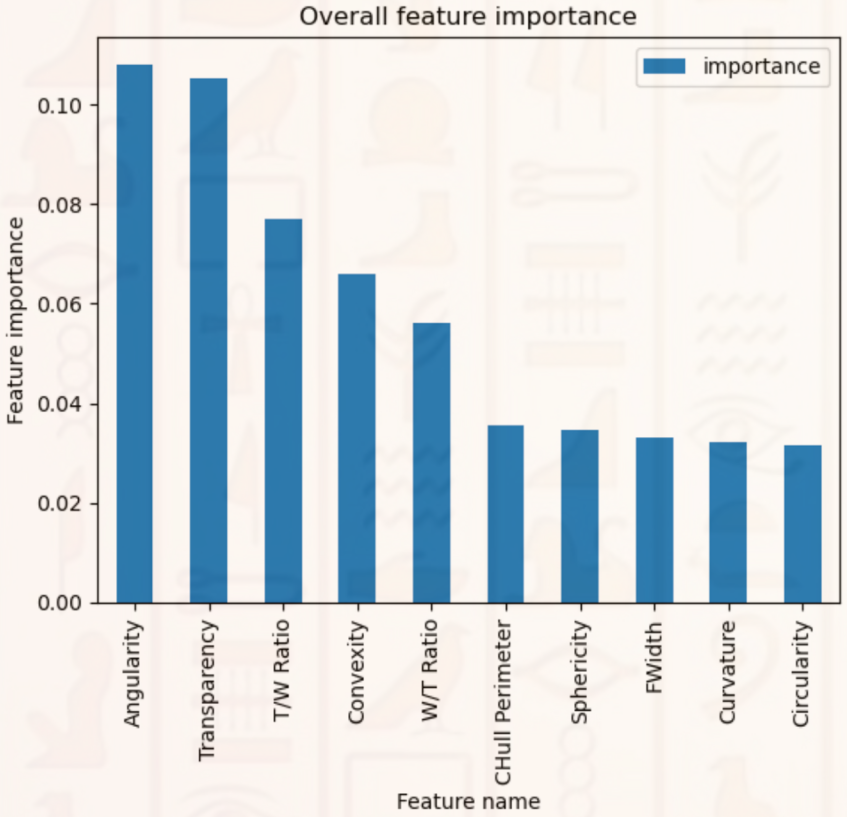
Methods & Results - Plot Trees (ArchaeologicalSoil No.100)



Lazy Predict	Top Performing Models	Feature Importance	Selected Features

Methods & Results - Feature Importance

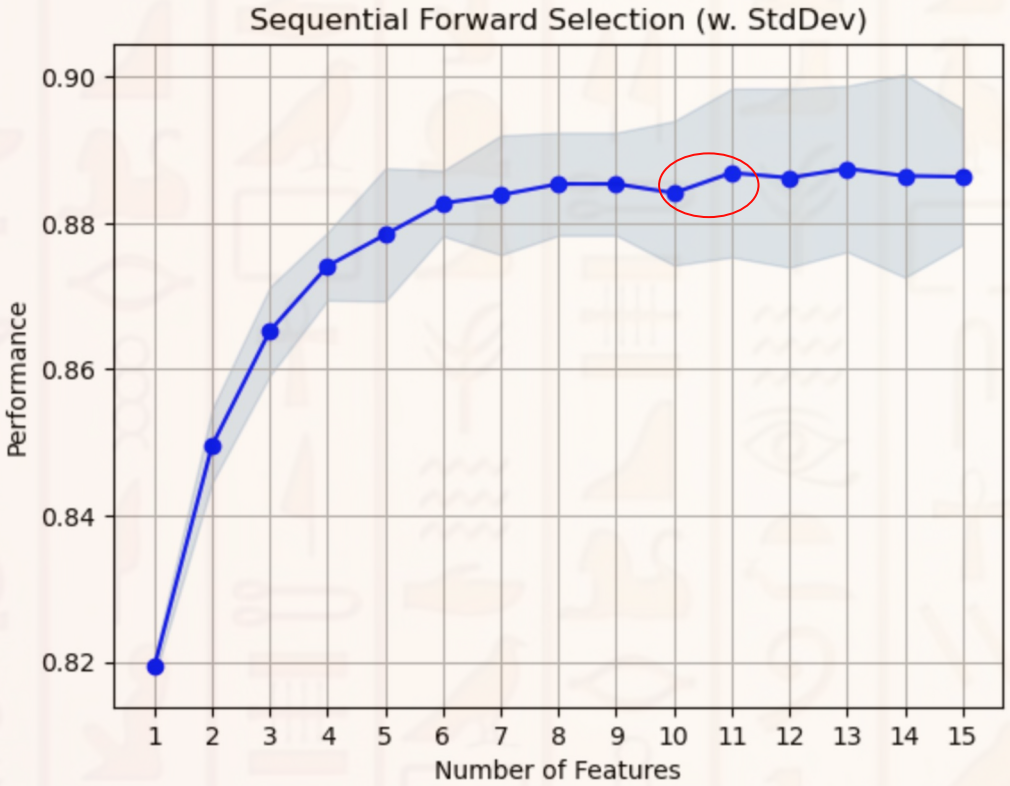
Variable Description multi-class



The top 10 important features are, to some degree, different from the 10 commonly used parameters cited in the documentation → 4 features

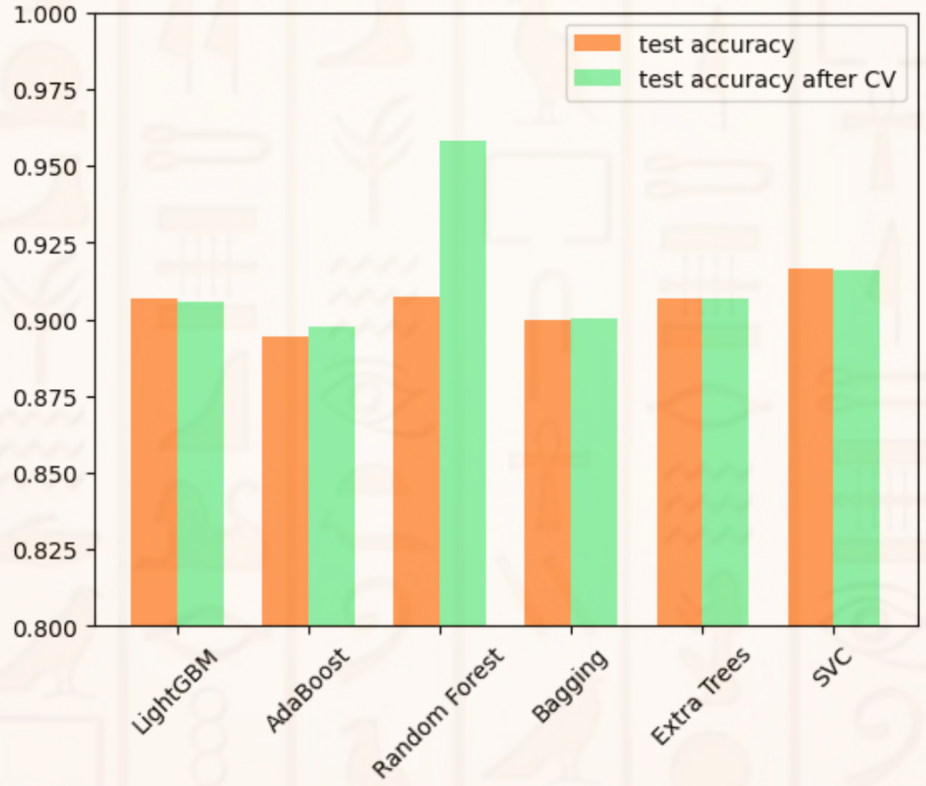
Da
FLength
W/L Aspect Ratio
L/W Aspect Ratio
FWidth
FThickness
Sphericity
Circularity
Convexity
Transparency

Performance for different number of Features



- Performance is still increasing at Features = 10 (line is not flat) → indicates more features are better
- This plot is for LGBM model, but this similar pattern is observed for all other tested models
- We did still achieve slightly better results using all features, rather than this subset

Methods & Results - Accuracy (Selected Features) (all)



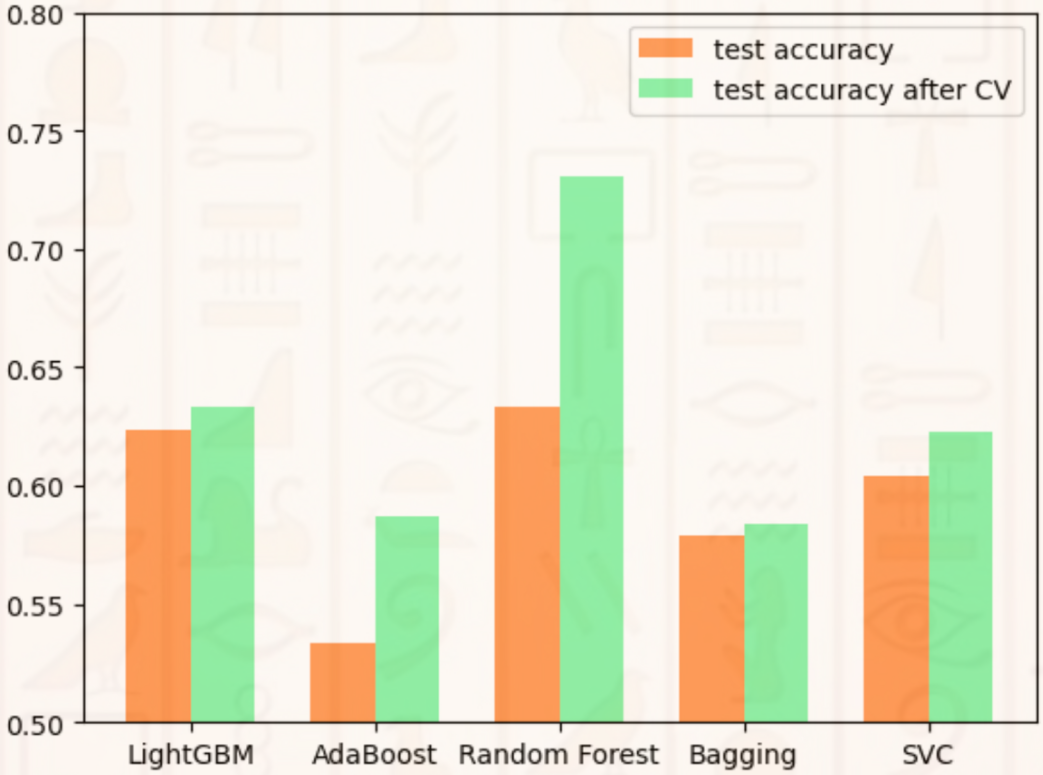
Methods & Results - Multi-class Classification (size)

Classes (4):

- 0.125mm
- 0.25mm
- 0.5mm
- >= 1mm (1mm & 2mm & 4mm)

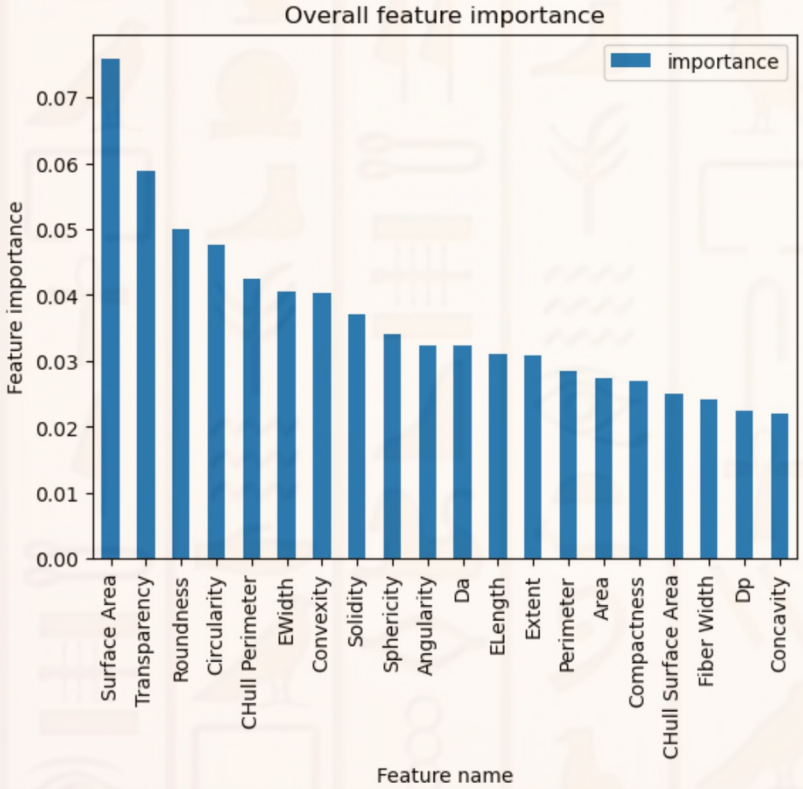
Model	Accuracy	Balanced Accuracy	ROC AUC	F1 Score	Time Taken
RandomForestClassifier	0.63	0.63	None	0.64	7.33
ExtraTreesClassifier	0.63	0.63	None	0.63	2.80
XGBClassifier	0.63	0.63	None	0.63	8.31
LGBMClassifier	0.62	0.62	None	0.63	1.22
BaggingClassifier	0.62	0.62	None	0.62	4.22
SVC	0.60	0.60	None	0.61	32.59
LinearSVC	0.58	0.58	None	0.58	12.70
NuSVC	0.58	0.58	None	0.58	56.69
LogisticRegression	0.57	0.57	None	0.58	0.70
CalibratedClassifierCV	0.57	0.57	None	0.57	47.84
DecisionTreeClassifier	0.57	0.57	None	0.57	0.71
QuadraticDiscriminantAnalysis	0.56	0.56	None	0.55	0.06
ExtraTreeClassifier	0.56	0.56	None	0.56	0.06
GaussianNB	0.55	0.55	None	0.54	0.06
LabelSpreading	0.55	0.55	None	0.55	22.19
LabelPropagation	0.55	0.55	None	0.55	14.05

Methods & Results - Multi-class Classification (size)



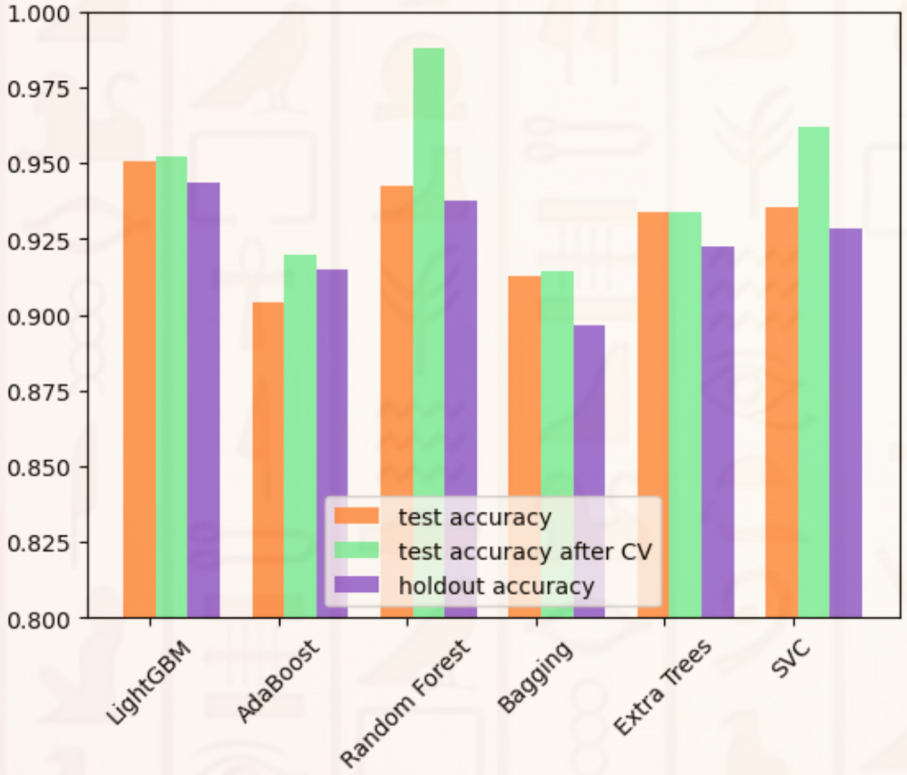
Methods & Results - Multi-class Classification (size)

binary



- Surface Area
- Transparency
- Roundness
- Circularity
- CHull Perimeter
- EWidth
- Convexity
- Solidity
- Sphericity
- Angularity

Discussion - Hold-out Set (all)



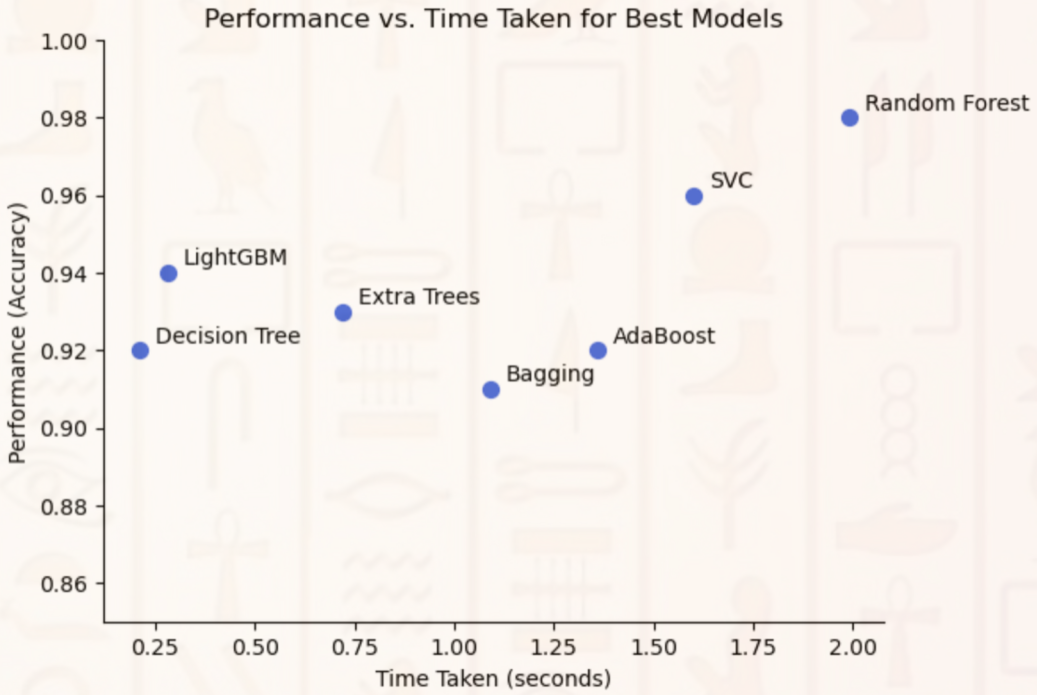
- LightGBM beats Random Forest on our holdout set for all combined data
- However, highest accuracy overall is still observed for Random Forest on the test set

Discussion - Results & Limitations

- **Random Forest** had the highest performance with all features after CV, with:
  - **100%** for experiment 9 data
  - **98.3%** for archaeological soil
  - **97.8%** for all of our data *combined*

- And with selected features (top 10):
  - **100%** for experiment 9 data
  - **96.7%** for archaeological soil
  - **95.8%** for all of our data *combined*

- We have a few other models that performed very similarly, most notable were **Decision Tree**, **LightGBM**, and **SVC**



Discussion - Next Steps

- Other sampling methods (extremely unbalanced data)
  - More training data of lithic
- Our variables were highly correlated which limited the models available to us (prior to dimension reduction)
- Edge cases
  - Much of the data is very distinctly stratified, so we need some more examples of edge cases
- Further exploration for our client:
  - Performance vs. Speed

Thank You

Q&A

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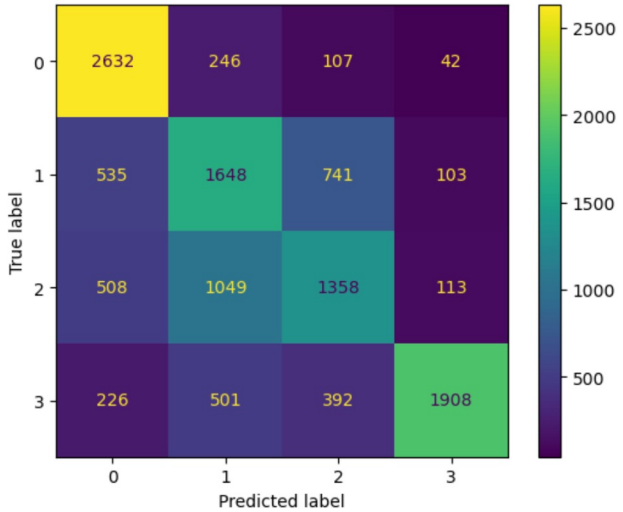
Appendix - Multi-class Classification

```
Accuracy of RF classifier on training set: 1.0000
Accuracy of RF classifier on test set: 0.6232
              precision    recall  f1-score   support

           0       0.67      0.87      0.76      3027
           1       0.48      0.54      0.51      3027
           2       0.52      0.45      0.48      3028
           3       0.88      0.63      0.73      3027

    accuracy                           0.62     12109
   macro avg       0.64      0.62      0.62     12109
weighted avg       0.64      0.62      0.62     12109
```

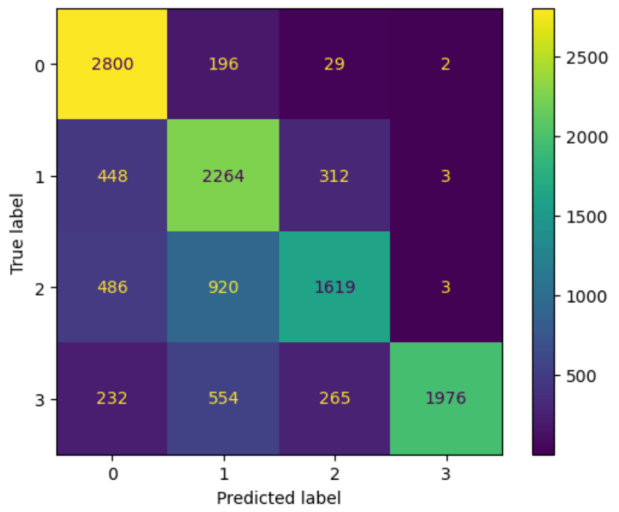


Best parameters:
'max_depth': 10,
'min_samples_split': 2
'n_estimators': 50

```
Accuracy of Random Forest classifier on training set: 0.6041
Accuracy of Random Forest classifier on test set: 0.7151
              precision    recall  f1-score   support

           0       0.71      0.93      0.80      3027
           1       0.58      0.75      0.65      3027
           2       0.73      0.53      0.62      3028
           3       1.00      0.65      0.79      3027

    accuracy                           0.72     12109
   macro avg       0.75      0.72      0.71     12109
weighted avg       0.75      0.72      0.71     12109
```



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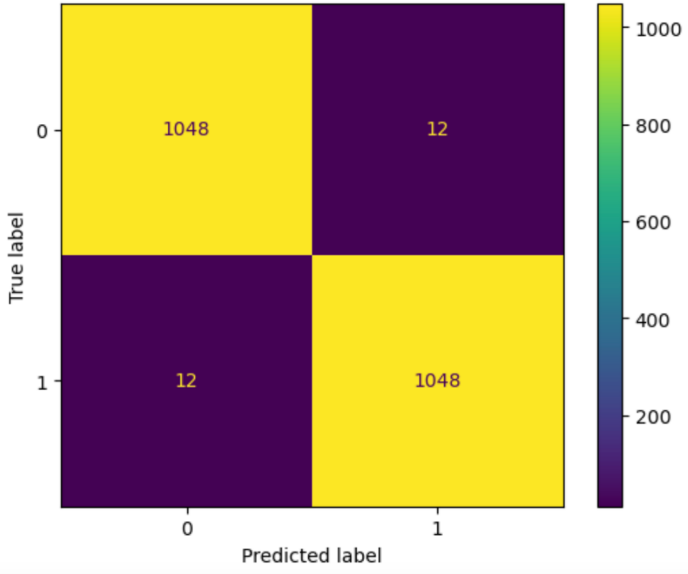
Appendix - 0.125mm undersampling

```
Accuracy of RF classifier on training set: 1.0000
Accuracy of RF classifier on test set: 0.9887
              precision    recall  f1-score   support

           0       0.99      0.99      0.99      1060
           1       0.99      0.99      0.99      1060

    accuracy                           0.99      2120
   macro avg       0.99      0.99      0.99      2120
weighted avg       0.99      0.99      0.99      2120
```

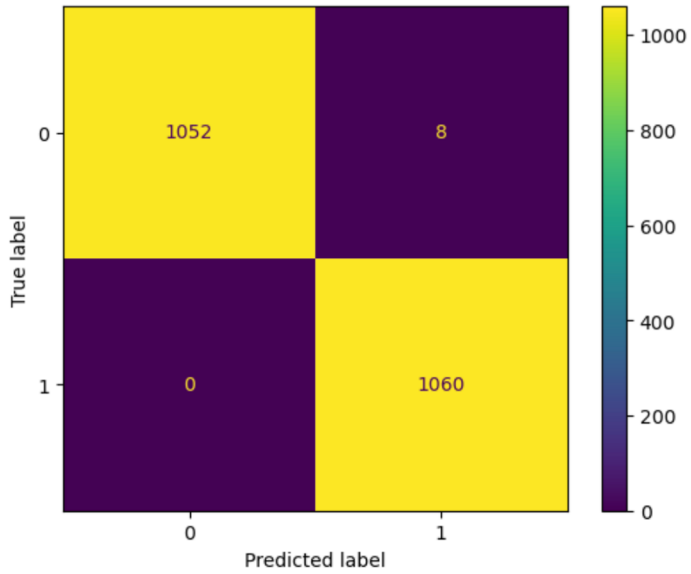


Best parameters:
'max_depth': 10,
'min_samples_split': 5
'n_estimators': 100

```
Accuracy of Random Forest classifier on training set: 0.9812
Accuracy of Random Forest classifier on test set: 0.9962
              precision    recall  f1-score   support

           0       1.00      0.99      1.00      1060
           1       0.99      1.00      1.00      1060

    accuracy                           1.00      2120
   macro avg       1.00      1.00      1.00      2120
weighted avg       1.00      1.00      1.00      2120
```



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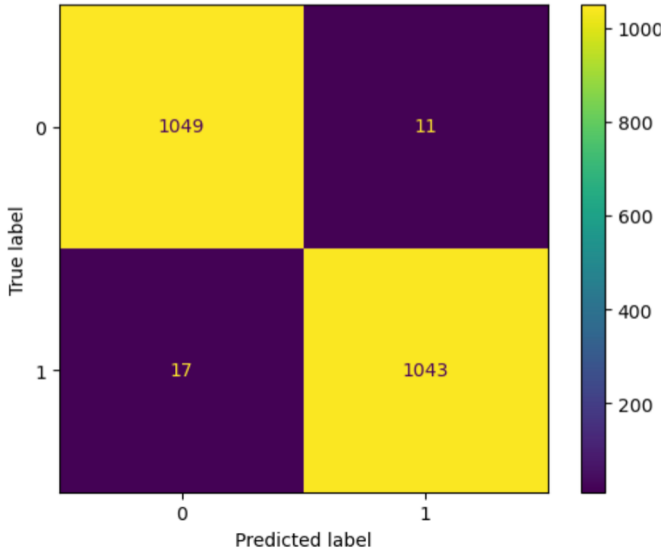
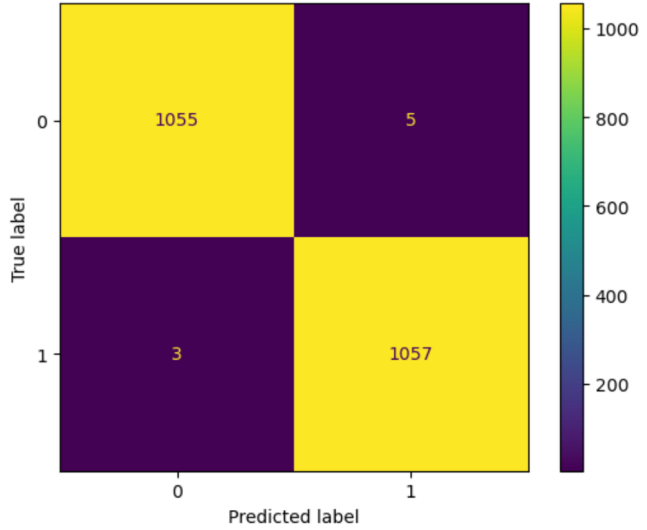
Appendix - 0.25mm undersampling

	precision	recall	f1-score	support
0	0.98	0.99	0.99	1060
1	0.99	0.98	0.99	1060
accuracy			0.99	2120
macro avg	0.99	0.99	0.99	2120
weighted avg	0.99	0.99	0.99	2120



Best parameters:
'C': 10'
gamma': 0.1
'kernel': 'rbf'

	precision	recall	f1-score	support
0	1.00	1.00	1.00	1060
1	1.00	1.00	1.00	1060
accuracy			1.00	2120
macro avg	1.00	1.00	1.00	2120
weighted avg	1.00	1.00	1.00	2120



Appendix - 0.5mm undersampling

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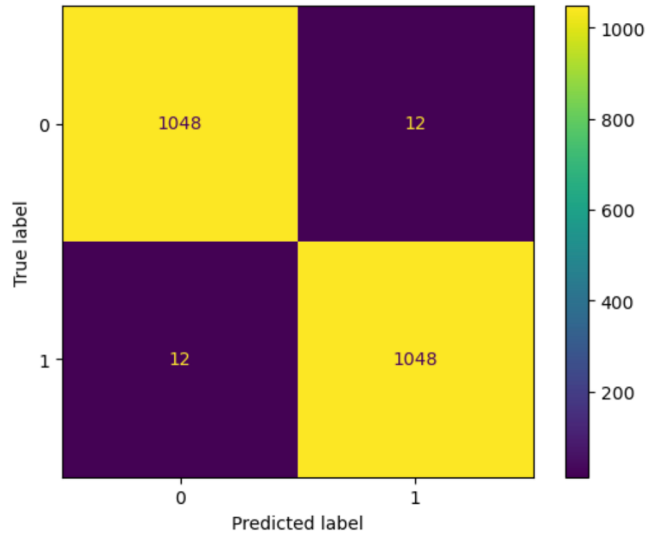
```
Accuracy of RF classifier on training set: 1.0000
Accuracy of RF classifier on test set: 0.9887
              precision    recall  f1-score   support

           0       0.99      0.99      0.99      1060
           1       0.99      0.99      0.99      1060

    accuracy                           0.99      2120
   macro avg       0.99      0.99      0.99      2120
weighted avg       0.99      0.99      0.99      2120
```

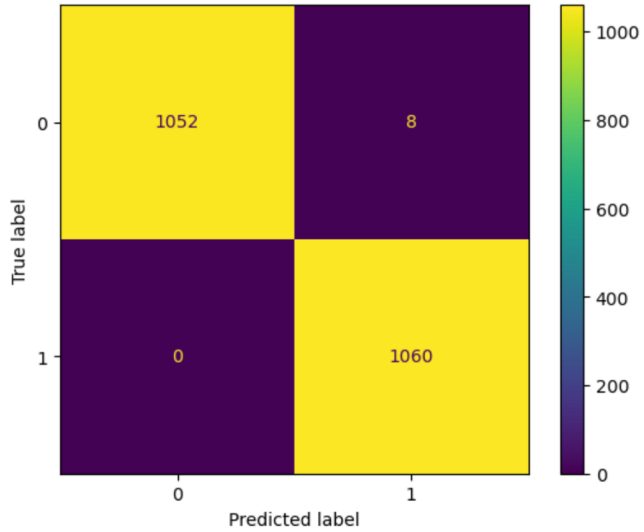


Best parameters:
'max_depth': 10,
'min_samples_split': 5
'n_estimators': 100

```
Accuracy of Random Forest classifier on training set: 0.9812
Accuracy of Random Forest classifier on test set: 0.9962
              precision    recall  f1-score   support

           0       1.00      0.99      1.00      1060
           1       0.99      1.00      1.00      1060

    accuracy                           1.00      2120
   macro avg       1.00      1.00      1.00      2120
weighted avg       1.00      1.00      1.00      2120
```



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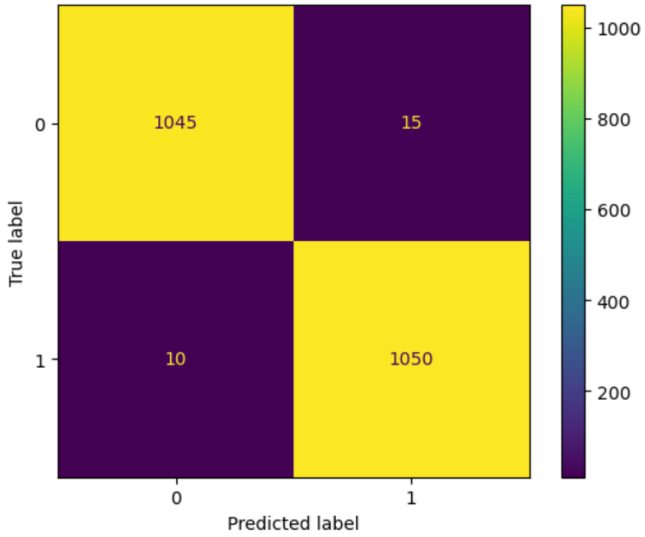
Appendix - 1mm undersampling

```
Accuracy of RF classifier on training set: 1.0000
Accuracy of RF classifier on test set: 0.9882
              precision    recall  f1-score   support

           0       0.99      0.99      0.99      1060
           1       0.99      0.99      0.99      1060

    accuracy                           0.99      2120
   macro avg       0.99      0.99      0.99      2120
weighted avg       0.99      0.99      0.99      2120
```

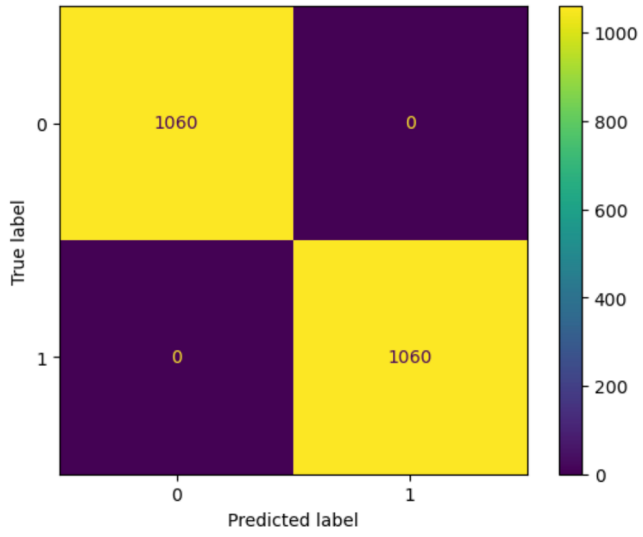


Best parameters:
'max_depth': None,
'min_samples_split': 2
'n_estimators': 100

```
Accuracy of Random Forest classifier on training set: 0.9756
Accuracy of Random Forest classifier on test set: 1.0000
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1060
           1       1.00      1.00      1.00      1060

    accuracy                           1.00      2120
   macro avg       1.00      1.00      1.00      2120
weighted avg       1.00      1.00      1.00      2120
```



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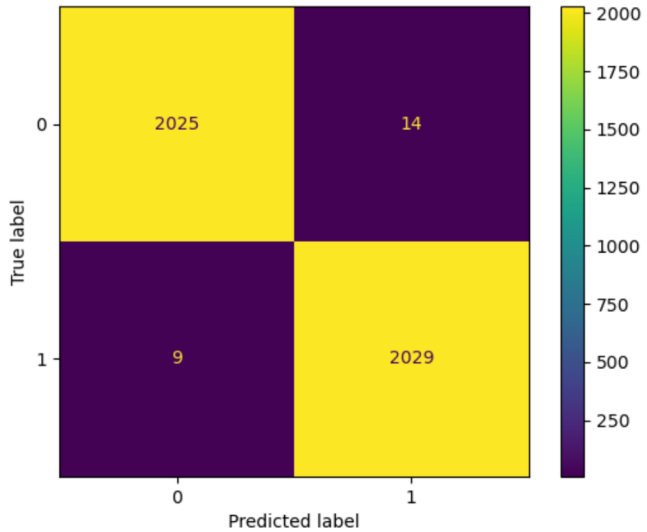
Appendix - 1mm oversampling

```
Accuracy of RF classifier on training set: 1.0000
Accuracy of RF classifier on test set: 0.9944
              precision    recall  f1-score   support

           0       1.00      0.99      0.99      2039
           1       0.99      1.00      0.99      2038

    accuracy                           0.99      4077
   macro avg       0.99      0.99      0.99      4077
weighted avg       0.99      0.99      0.99      4077
```

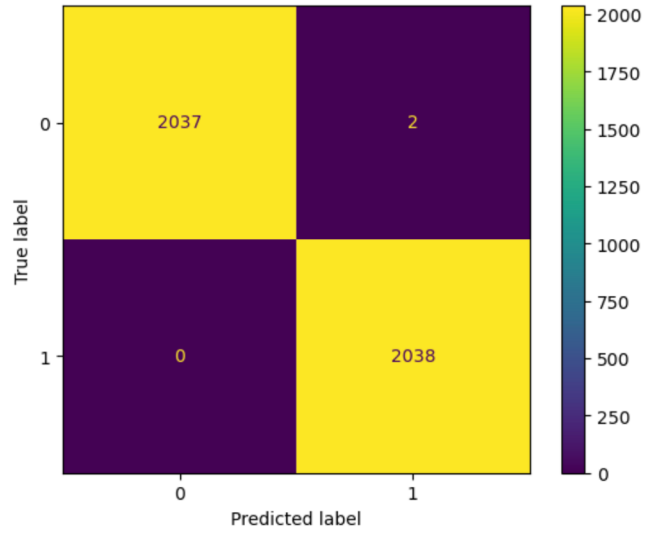


Best parameters:
'max_depth': None,
'min_samples_split': 5
'n_estimators': 100

```
Accuracy of Random Forest classifier on training set: 0.9825
Accuracy of Random Forest classifier on test set: 0.9995
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      2039
           1       1.00      1.00      1.00      2038

    accuracy                           1.00      4077
   macro avg       1.00      1.00      1.00      4077
weighted avg       1.00      1.00      1.00      4077
```



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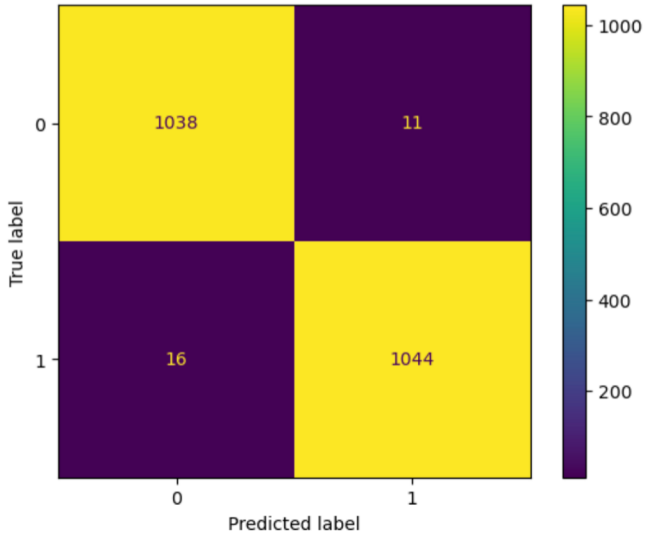
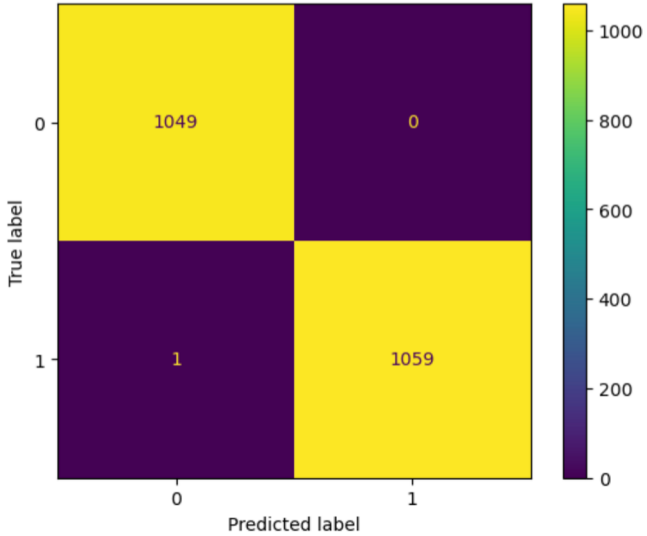
Appendix - 2&4mm SMOTETomek

	precision	recall	f1-score	support
0	0.98	0.99	0.99	1049
1	0.99	0.98	0.99	1060
accuracy			0.99	2109
macro avg	0.99	0.99	0.99	2109
weighted avg	0.99	0.99	0.99	2109



Best parameters:
'C': 10'
gamma': 0.1
'kernel': 'rbf'

	precision	recall	f1-score	support
0	1.00	1.00	1.00	1049
1	1.00	1.00	1.00	1060
accuracy			1.00	2109
macro avg	1.00	1.00	1.00	2109
weighted avg	1.00	1.00	1.00	2109



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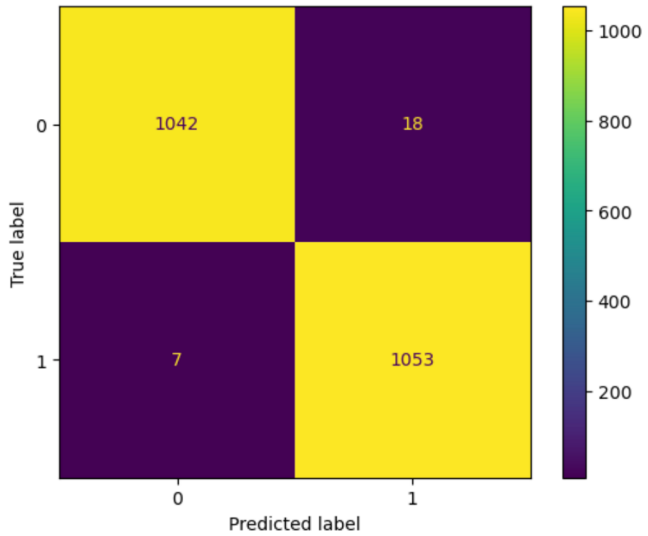
Appendix - Experiment 9

```
Accuracy of RF classifier on training set: 1.0000
Accuracy of RF classifier on test set: 0.9882
              precision    recall  f1-score   support

           0       0.99      0.98      0.99      1060
           1       0.98      0.99      0.99      1060

    accuracy                           0.99      2120
   macro avg       0.99      0.99      0.99      2120
weighted avg       0.99      0.99      0.99      2120
```

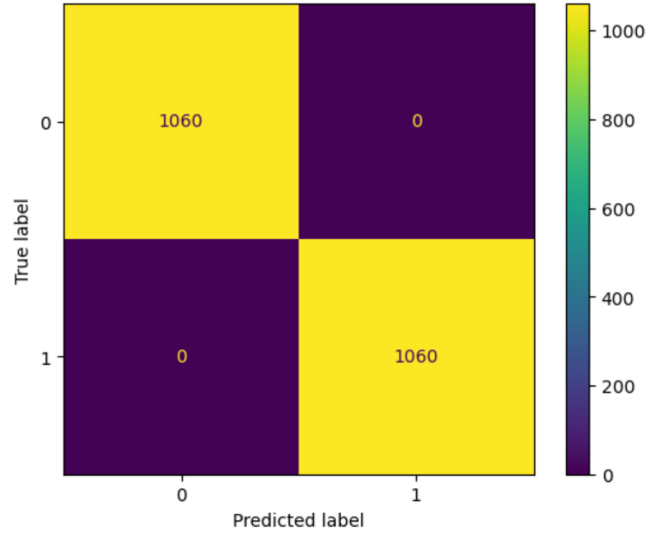


Best parameters:
'max_depth': None,
'min_samples_split': 5
'n_estimators': 100

```
Accuracy of Random Forest classifier on training set: 0.9781
Accuracy of Random Forest classifier on test set: 1.0000
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1060
           1       1.00      1.00      1.00      1060

    accuracy                           1.00      2120
   macro avg       1.00      1.00      1.00      2120
weighted avg       1.00      1.00      1.00      2120
```



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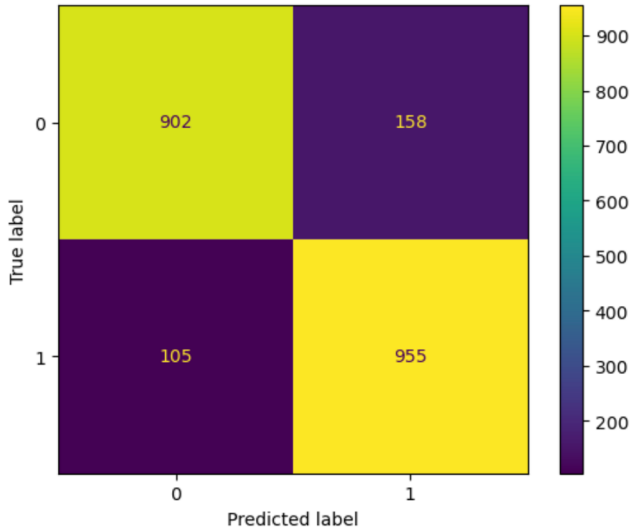
Appendix - Archaeological Soil

```
Accuracy of RF classifier on training set: 0.9881
Accuracy of RF classifier on test set: 0.8759
              precision    recall  f1-score   support

           0       0.90      0.85      0.87      1060
           1       0.86      0.90      0.88      1060

    accuracy                           0.88      2120
   macro avg       0.88      0.88      0.88      2120
weighted avg       0.88      0.88      0.88      2120
```

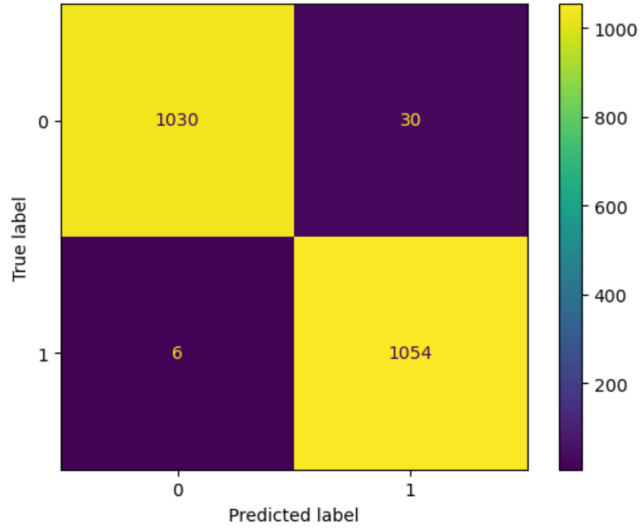


Best parameters:
'max_depth': None,
'min_samples_split': 5
'n_estimators': 100

```
Accuracy of Random Forest classifier on training set: 0.8653
Accuracy of Random Forest classifier on test set: 0.9830
              precision    recall  f1-score   support

           0       0.99      0.97      0.98      1060
           1       0.97      0.99      0.98      1060

    accuracy                           0.98      2120
   macro avg       0.98      0.98      0.98      2120
weighted avg       0.98      0.98      0.98      2120
```



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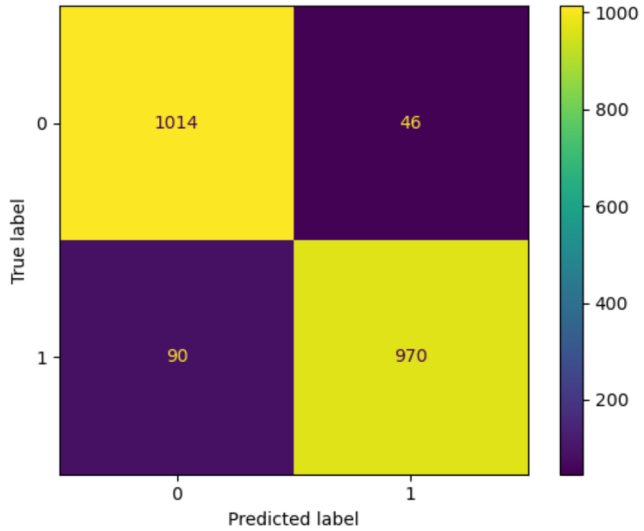
Appendix - all

```
Accuracy of RF classifier on training set: 0.9932
Accuracy of RF classifier on test set: 0.9358
              precision    recall  f1-score   support

           0       0.92      0.96      0.94      1060
           1       0.95      0.92      0.93      1060

    accuracy                           0.94      2120
   macro avg       0.94      0.94      0.94      2120
weighted avg       0.94      0.94      0.94      2120
```

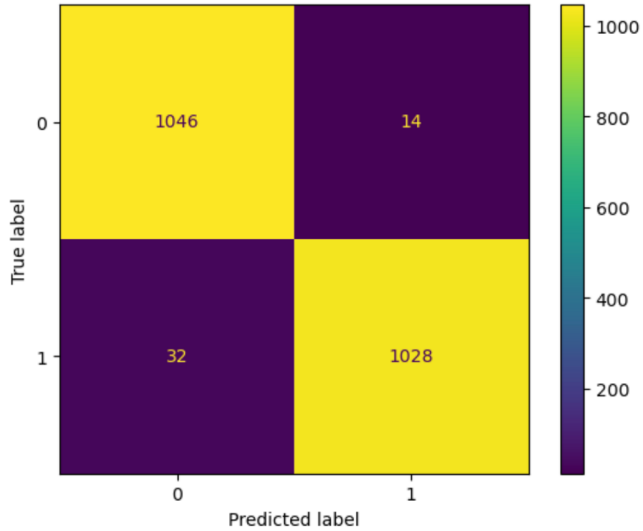


Best parameters:
'max_depth': None,
'min_samples_split': 5
'n_estimators': 100

```
Accuracy of Random Forest classifier on training set: 0.9150
Accuracy of Random Forest classifier on test set: 0.9783
              precision    recall  f1-score   support

           0       0.97      0.99      0.98      1060
           1       0.99      0.97      0.98      1060

    accuracy                           0.98      2120
   macro avg       0.98      0.98      0.98      2120
weighted avg       0.98      0.98      0.98      2120
```



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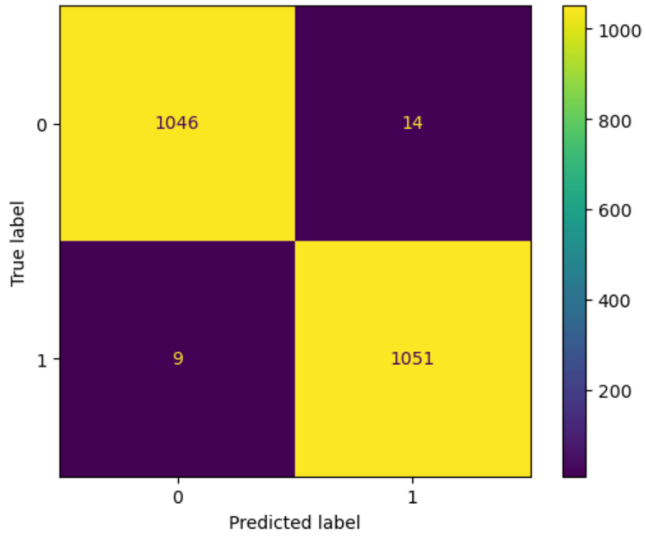
Appendix - Selected Features (Experiment 9)

```
Accuracy of RF classifier on training set: 1.0000
Accuracy of RF classifier on test set: 0.9892
              precision    recall  f1-score   support

           0       0.99      0.99      0.99      1060
           1       0.99      0.99      0.99      1060

    accuracy                           0.99      2120
   macro avg       0.99      0.99      0.99      2120
weighted avg       0.99      0.99      0.99      2120
```

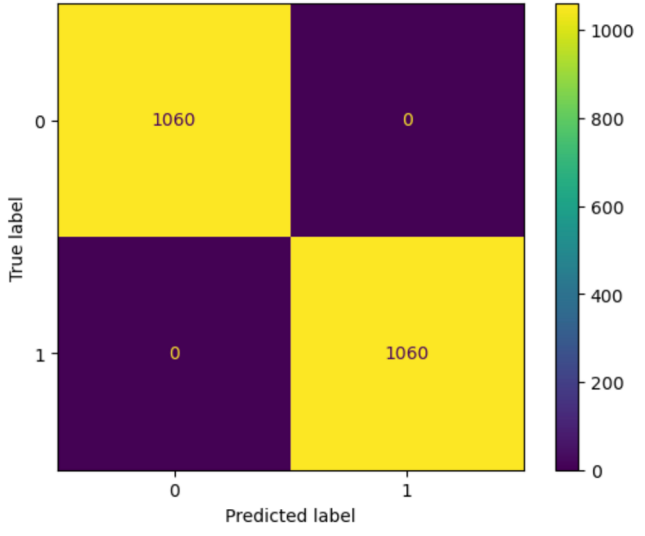


Best parameters:
'max_depth': 10,
'min_samples_split': 2
'n_estimators': 100

```
Accuracy of Random Forest classifier on training set: 0.9785
Accuracy of Random Forest classifier on test set: 1.0000
              precision    recall  f1-score   support

           0       1.00      1.00      1.00      1060
           1       1.00      1.00      1.00      1060

    accuracy                           1.00      2120
   macro avg       1.00      1.00      1.00      2120
weighted avg       1.00      1.00      1.00      2120
```



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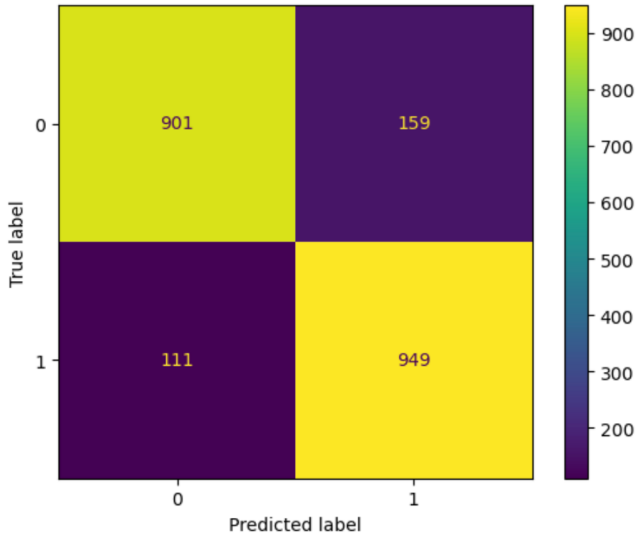
Appendix - Selected Features (Archaeological Soil)

```
Accuracy of RF classifier on training set: 0.9881
Accuracy of RF classifier on test set: 0.8726
              precision    recall  f1-score   support

           0       0.89      0.85      0.87      1060
           1       0.86      0.90      0.88      1060

    accuracy                           0.87      2120
   macro avg       0.87      0.87      0.87      2120
weighted avg       0.87      0.87      0.87      2120
```

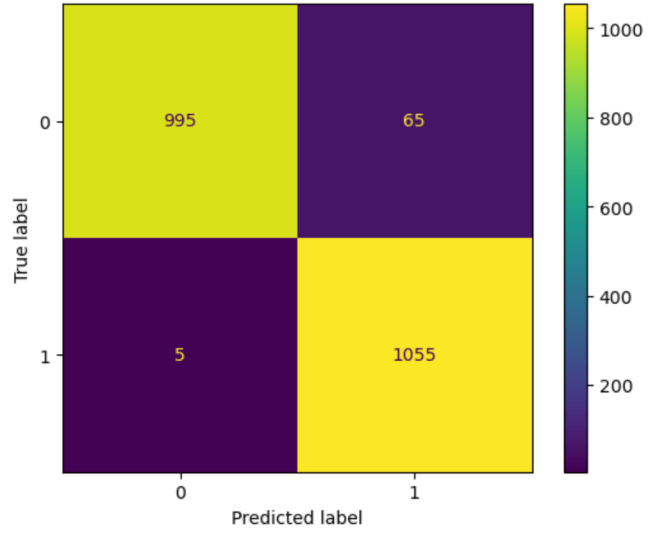


Best parameters:
'max_depth': 10,
'min_samples_split': 2
'n_estimators': 50

```
Accuracy of Random Forest classifier on training set: 0.8666
Accuracy of Random Forest classifier on test set: 0.9670
              precision    recall  f1-score   support

           0       0.99      0.94      0.97      1060
           1       0.94      1.00      0.97      1060

    accuracy                           0.97      2120
   macro avg       0.97      0.97      0.97      2120
weighted avg       0.97      0.97      0.97      2120
```



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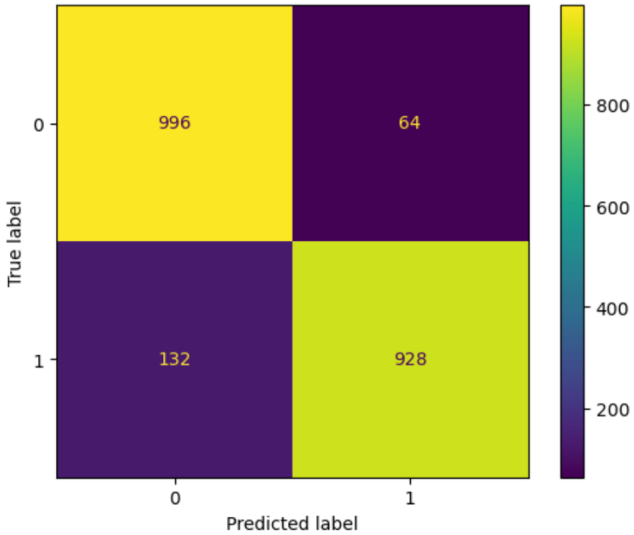
Appendix - Selected Features (all)

```
Accuracy of RF classifier on training set: 0.9828
Accuracy of RF classifier on test set: 0.9075
              precision    recall  f1-score   support

           0       0.88      0.94      0.91      1060
           1       0.94      0.88      0.90      1060

    accuracy                           0.91      2120
   macro avg       0.91      0.91      0.91      2120
weighted avg       0.91      0.91      0.91      2120
```

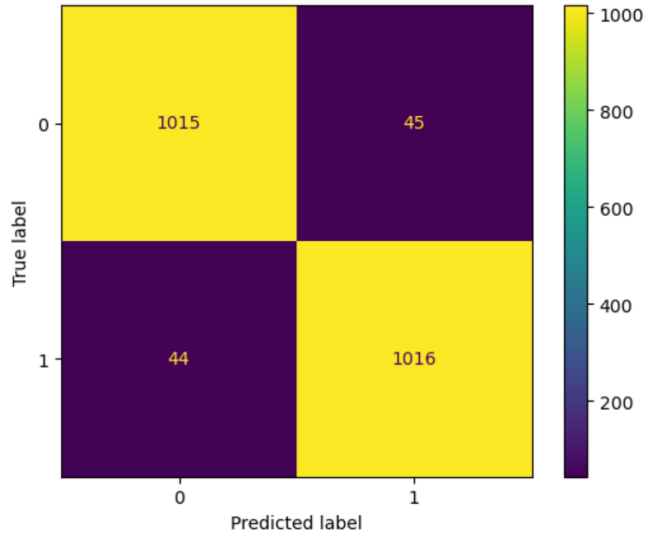


Best parameters:
'max_depth': 10,
'min_samples_split': 2
'n_estimators': 10

```
Accuracy of Random Forest classifier on training set: 0.8947
Accuracy of Random Forest classifier on test set: 0.9580
              precision    recall  f1-score   support

           0       0.96      0.96      0.96      1060
           1       0.96      0.96      0.96      1060

    accuracy                           0.96      2120
   macro avg       0.96      0.96      0.96      2120
weighted avg       0.96      0.96      0.96      2120
```



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Appendix - Feature Descriptions

Listing of Microtrac Morphological Parameters by Primary Characterization Groups			
Size	**Shape/Form**	**Surface Roughness**	**Intensity**
Da**	Sphericity**	Convexity**	Transparency**
Dp	Circularity**	Solidity	Curvature
FLength**	Roundness	Concavity	
FWidth**	Krumbein Roundness		
FThickness** (3D Only)	Extent		
ELength	Ellipse Ratio		
EWidth	W/L Aspect Ratio**		
EThickness (3D Only)	L/W Aspect Ratio**		
Actual Area	T/L Aspect Ratio (3D Only)		
Actual Perimeter	L/T Ratio (3D Only)		
Volume	T/W Ratio (3D Only)		
Surface Area	W/T Ratio (3D Only)		
CHull Area	Ellipticity		
CHull Perimeter			
CHull Surface Area	Angularity		
Sieve (3D Only)	Rectangularity (3D Only)		
Cylinder Diameter (3D Only)	Compactness		
Cylinder Length (3D Only)			
Fiber Length			
Fiber Width			

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Fiber Width			