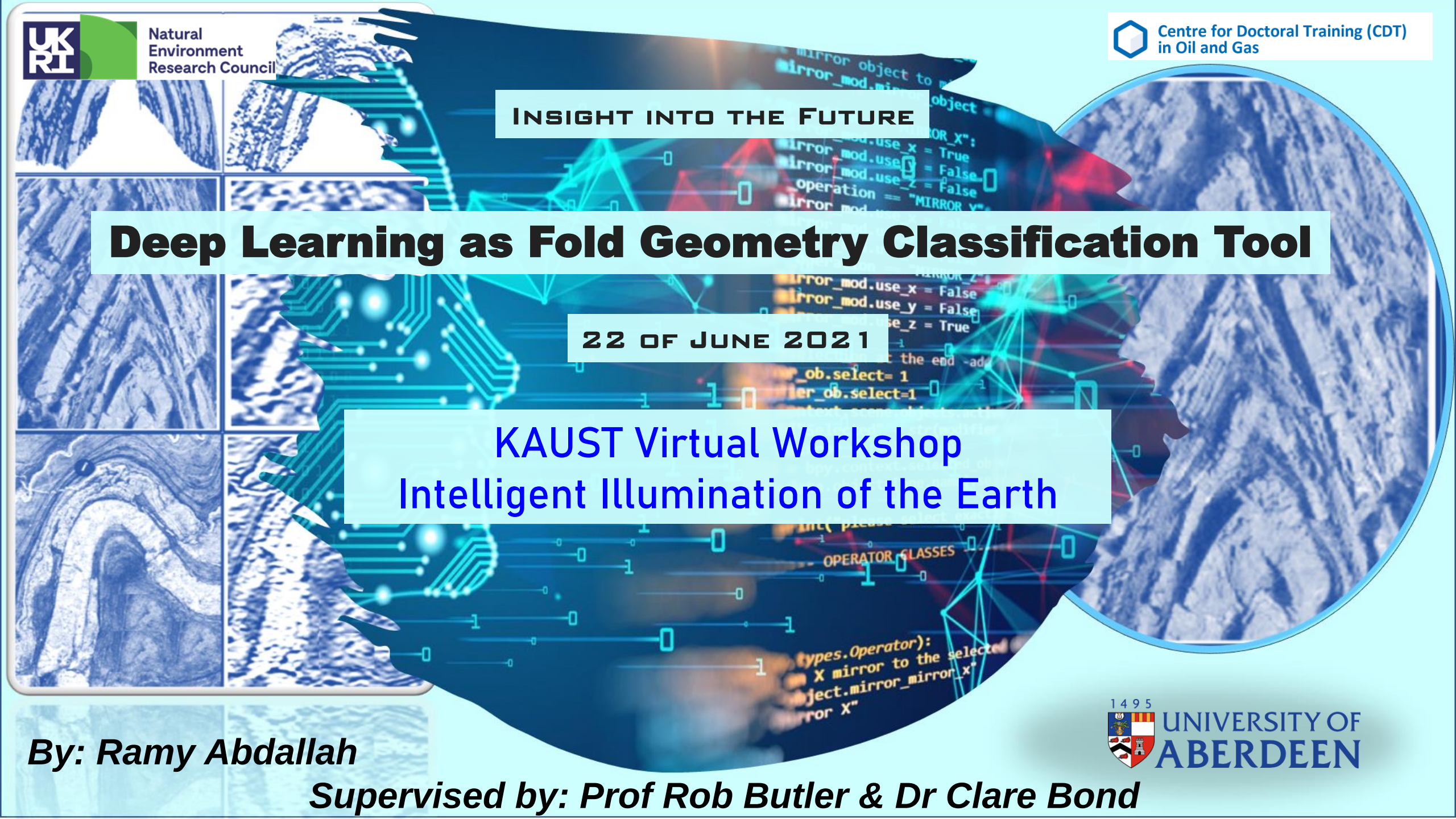


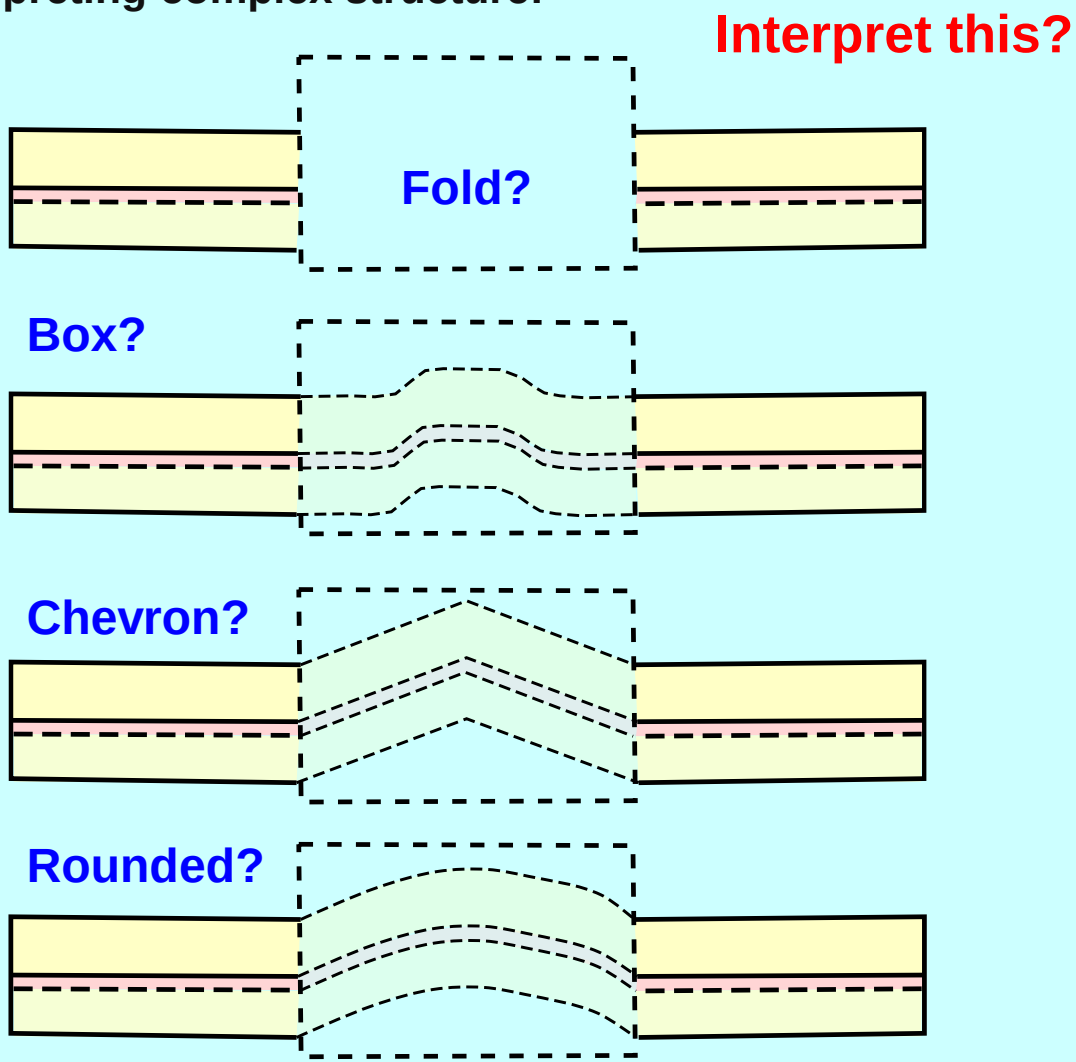

By: Ramy Abdallah

Supervised by: Prof Rob Butler & Dr Clare Bond

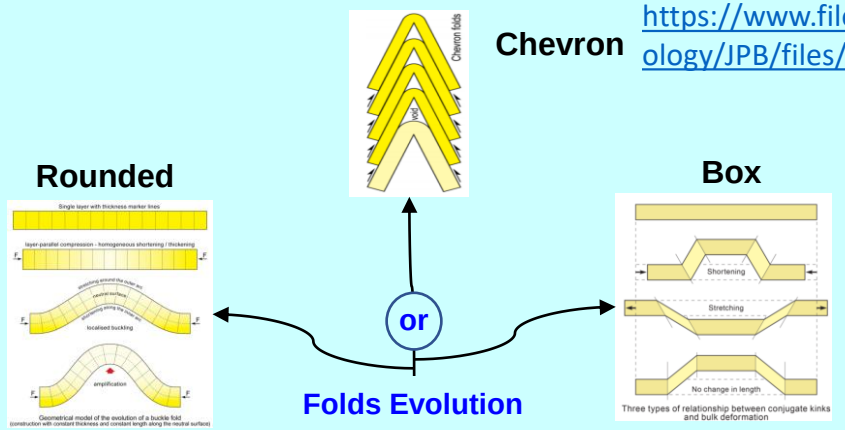
# Why perform fold classification?



**1. Provide additional information and constraints when interpreting complex structure:**

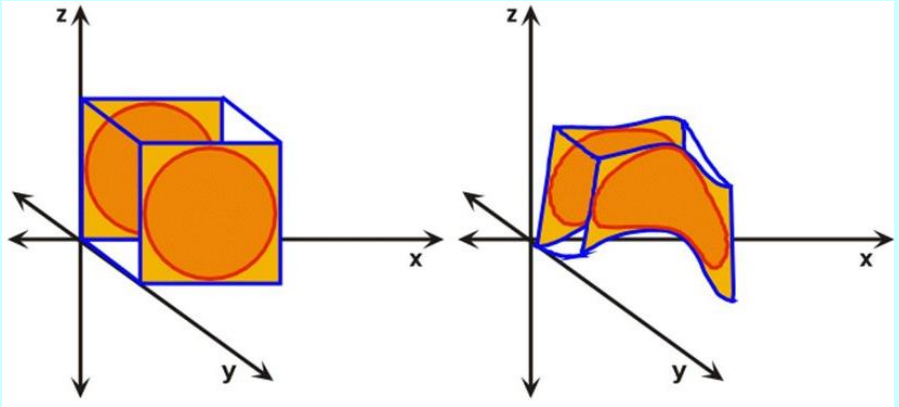



**2. Helps to understand folding mechanisms and development:**




**3. Helps to understand distribution and heterogeneity of strain:**

Heterogeneous or Inhomogeneous Strain

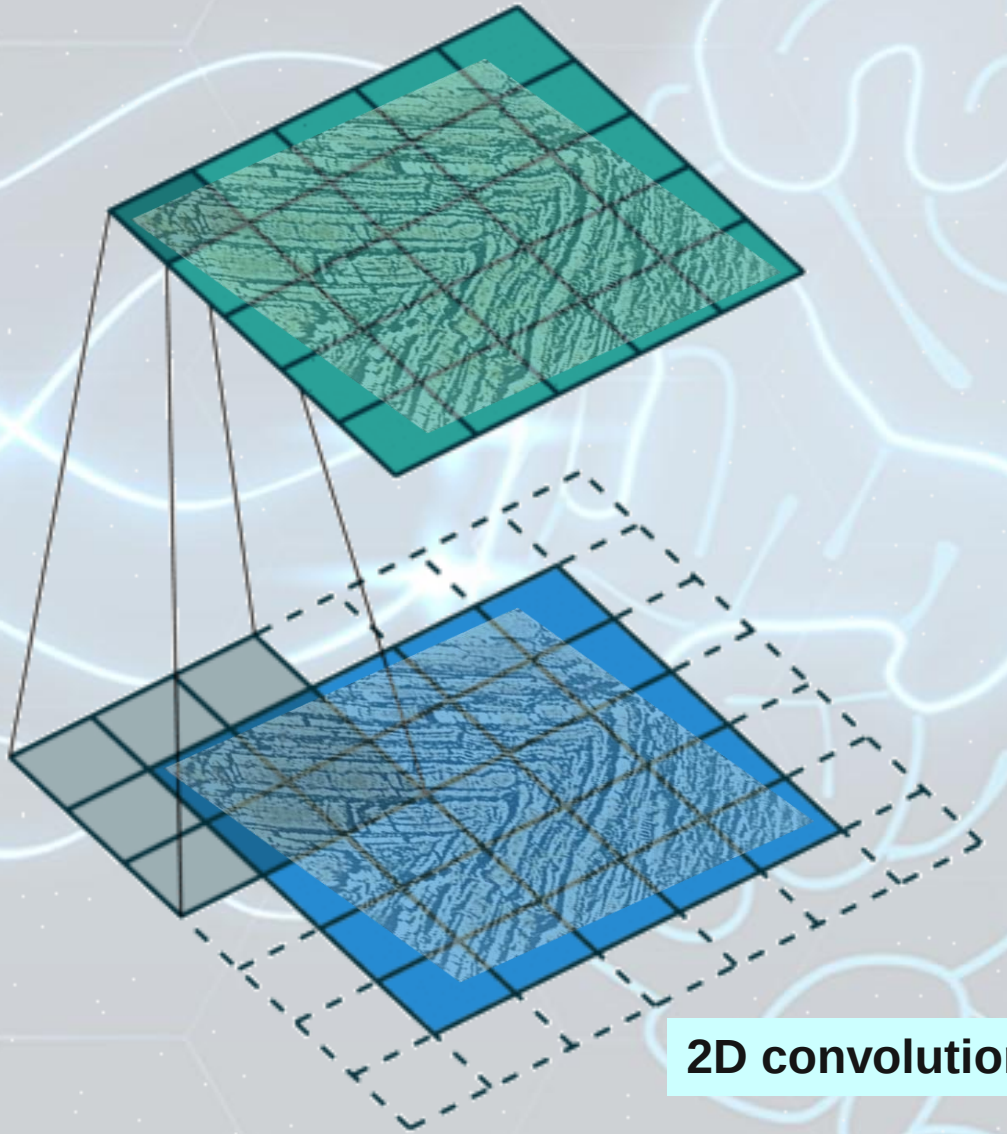


# Image Classification

## Using 2D Convolutional Neural Networks



https://towardsdatascience.com/intuitively-understanding-convolutions-for-deep-learning-1f6f42faee1

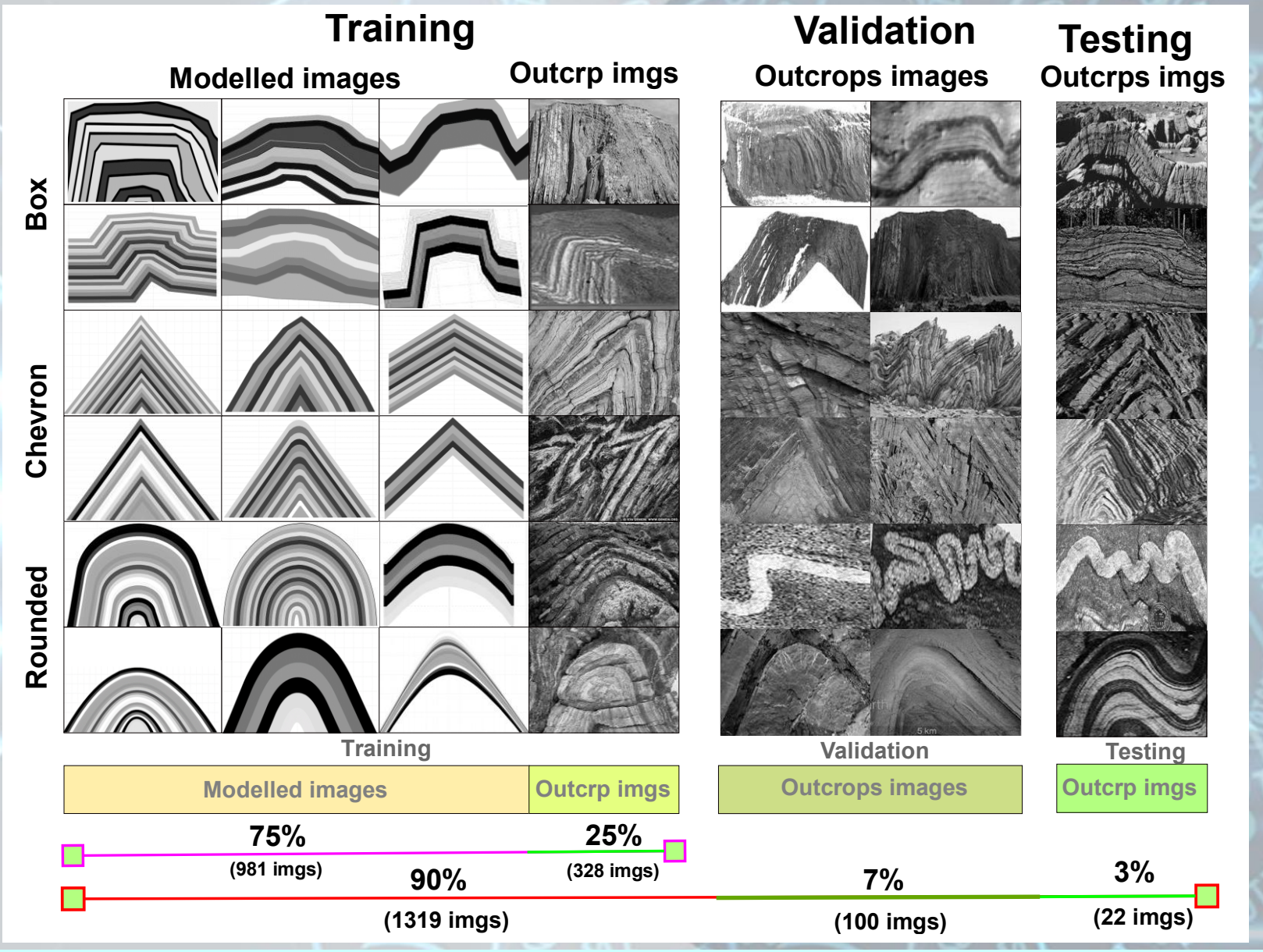


2D convolution operation

- Start with a kernel, which is simply a small matrix of weights.
- This kernel “slides” over the 2D input data, performing an elementwise multiplication with the part of the input it is currently on.
- Then summing up the results into a single output pixel.

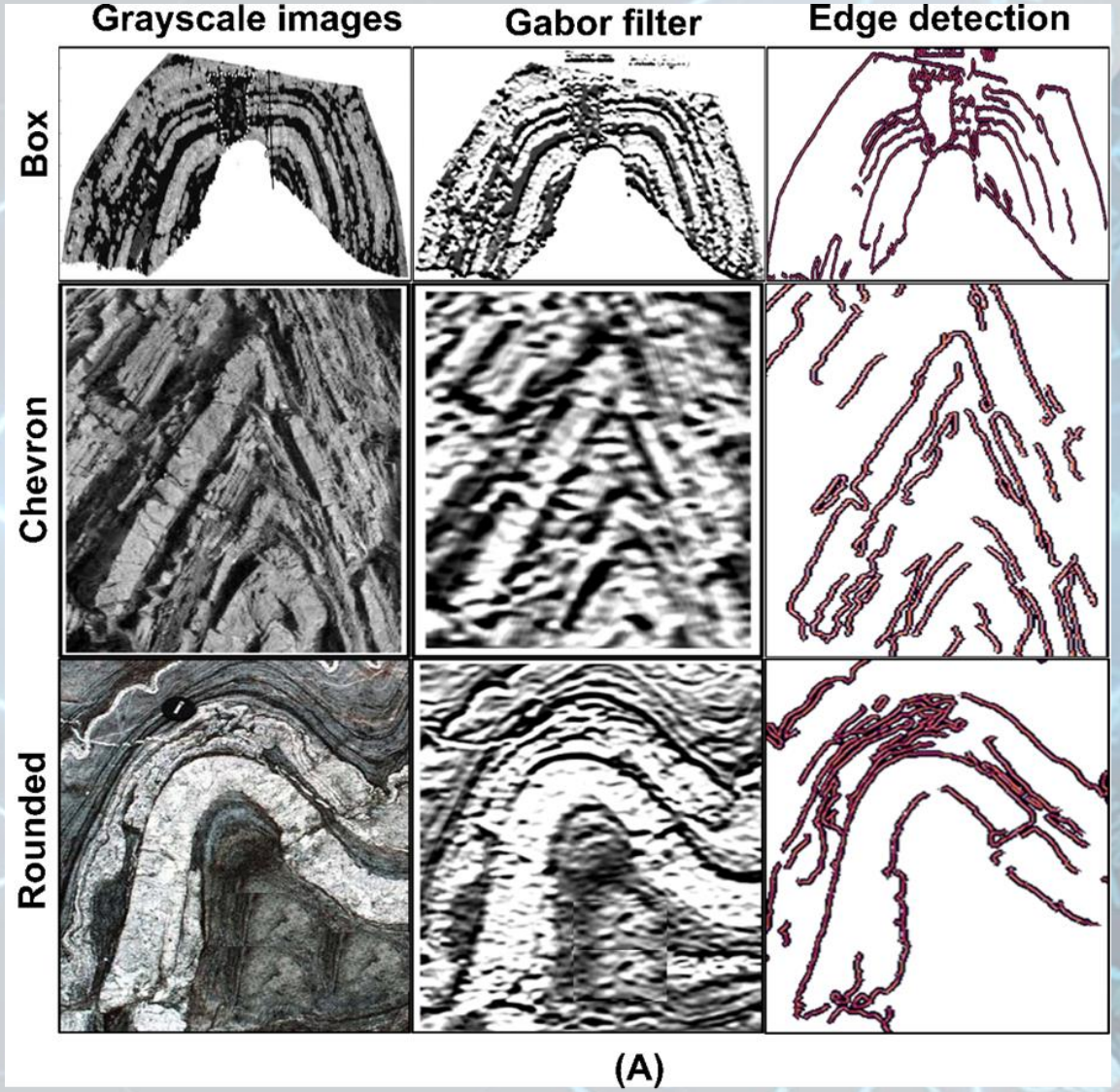
# Shape of Hinges Dataset

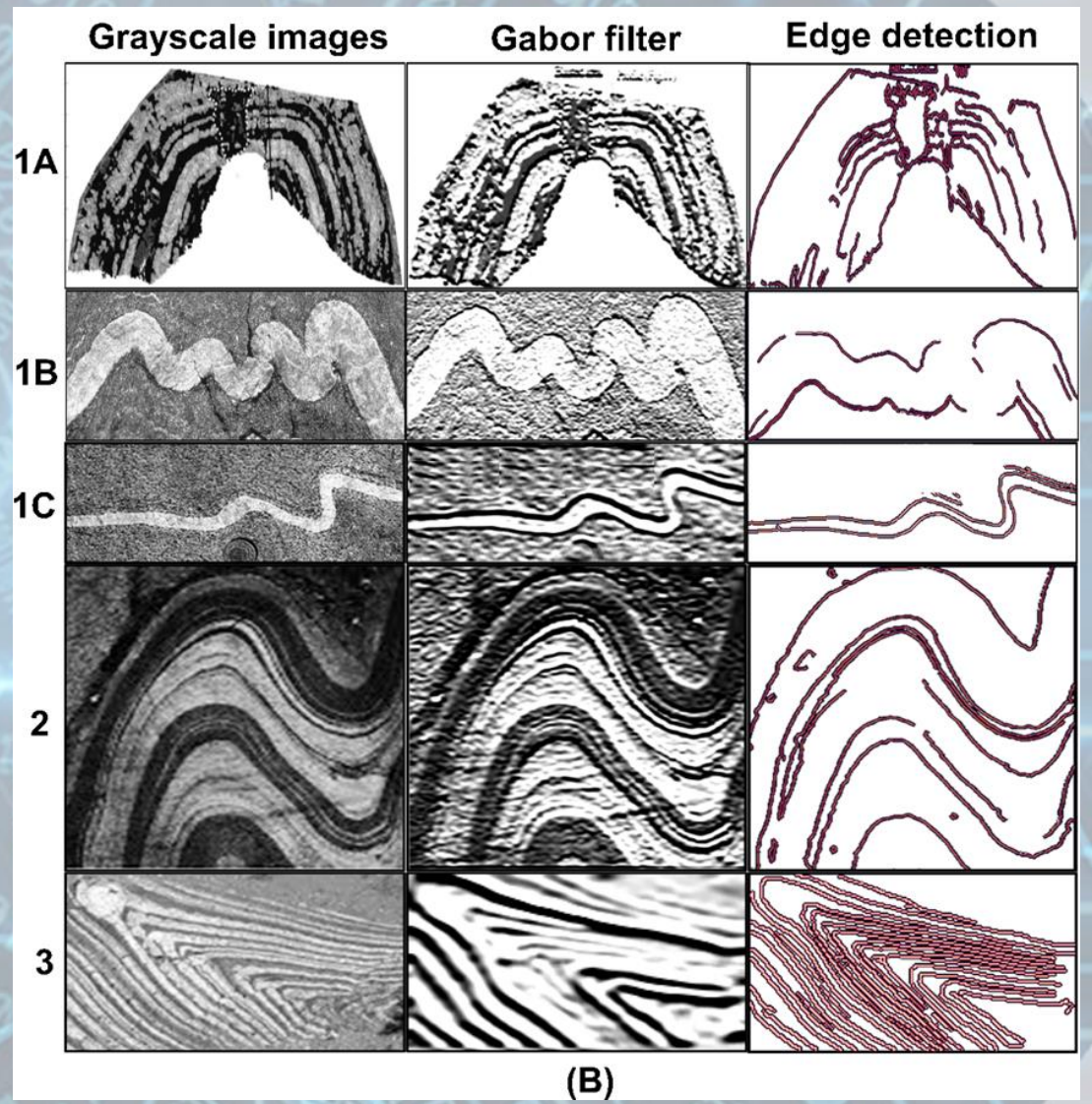




# Shallow Learning - Feature Extraction






Example of features extracted: Coloured, grayscale, original, Gabor, edge, noise, mean, std.

# Shallow Learning - Results



| Model | Accuracy | Balanced Accuracy | ROC AUC | F1 Score | Time Taken |
|---|---|---|---|---|---|
| RandomForestClassifier | 0.64 | 0.64 | None | 0.64 | 3.30 |
| ExtraTreesClassifier | 0.64 | 0.64 | None | 0.64 | 1.16 |
| LabelSpreading | 0.60 | 0.60 | None | 0.60 | 2.19 |
| LabelPropagation | 0.60 | 0.60 | None | 0.60 | 1.82 |
| LGBMClassifier | 0.60 | 0.60 | None | 0.60 | 1.87 |
| BaggingClassifier | 0.59 | 0.59 | None | 0.59 | 2.15 |
| XGBClassifier | 0.59 | 0.59 | None | 0.59 | 4.14 |
| ExtraTreeClassifier | 0.56 | 0.56 | None | 0.56 | 0.07 |
| KNeighborsClassifier | 0.50 | 0.50 | None | 0.50 | 0.27 |
| SGDClassifier | 0.49 | 0.49 | None | 0.46 | 0.29 |
| DecisionTreeClassifier | 0.49 | 0.49 | None | 0.49 | 0.41 |
| NuSVC | 0.48 | 0.48 | None | 0.48 | 2.78 |
| CalibratedClassifierCV | 0.48 | 0.48 | None | 0.48 | 10.73 |
| SVC | 0.47 | 0.47 | None | 0.47 | 1.62 |
| Perceptron | 0.47 | 0.47 | None | 0.46 | 0.08 |
| RidgeClassifier | 0.47 | 0.47 | None | 0.47 | 0.09 |
| LinearDiscriminantAnalysis | 0.46 | 0.46 | None | 0.46 | 0.16 |
| RidgeClassifierCV | 0.46 | 0.46 | None | 0.46 | 0.12 |
| LinearSVC | 0.46 | 0.46 | None | 0.46 | 2.94 |
| LogisticRegression | 0.45 | 0.45 | None | 0.45 | 0.41 |
| AdaBoostClassifier | 0.40 | 0.40 | None | 0.40 | 2.63 |
| QuadraticDiscriminantAnalysis | 0.39 | 0.39 | None | 0.39 | 0.14 |
| PassiveAggressiveClassifier | 0.38 | 0.38 | None | 0.32 | 0.14 |
| GaussianNB | 0.34 | 0.34 | None | 0.28 | 0.05 |
| NearestCentroid | 0.33 | 0.33 | None | 0.20 | 0.05 |
| BernoulliNB | 0.31 | 0.31 | None | 0.17 | 0.06 |
| DummyClassifier | 0.30 | 0.30 | None | 0.30 | 0.05 |

- **Validation dataset**

- **Maximum Accuracy of 64%**

| Model | Accuracy | Balanced Accuracy | ROC AUC | F1 Score | Time Taken |
|---|---|---|---|---|---|
| XGBClassifier | 0.63 | 0.63 | None | 0.63 | 4.02 |
| LGBMClassifier | 0.59 | 0.58 | None | 0.56 | 2.08 |
| ExtraTreesClassifier | 0.57 | 0.57 | None | 0.56 | 1.00 |
| RandomForestClassifier | 0.57 | 0.57 | None | 0.55 | 3.31 |
| DecisionTreeClassifier | 0.53 | 0.53 | None | 0.52 | 0.40 |
| BaggingClassifier | 0.53 | 0.53 | None | 0.50 | 2.28 |
| CalibratedClassifierCV | 0.53 | 0.52 | None | 0.52 | 11.40 |
| LinearSVC | 0.53 | 0.52 | None | 0.50 | 2.88 |
| LogisticRegression | 0.51 | 0.51 | None | 0.50 | 0.40 |
| SGDClassifier | 0.49 | 0.49 | None | 0.45 | 0.32 |
| NuSVC | 0.49 | 0.48 | None | 0.45 | 2.69 |
| LinearDiscriminantAnalysis | 0.49 | 0.48 | None | 0.46 | 0.12 |
| RidgeClassifierCV | 0.49 | 0.48 | None | 0.46 | 0.12 |
| RidgeClassifier | 0.49 | 0.47 | None | 0.45 | 0.08 |
| KNeighborsClassifier | 0.47 | 0.47 | None | 0.47 | 0.13 |
| QuadraticDiscriminantAnalysis | 0.47 | 0.47 | None | 0.47 | 0.11 |
| LabelPropagation | 0.47 | 0.47 | None | 0.46 | 1.56 |
| LabelSpreading | 0.47 | 0.47 | None | 0.46 | 2.12 |
| PassiveAggressiveClassifier | 0.46 | 0.46 | None | 0.42 | 0.12 |
| Perceptron | 0.47 | 0.46 | None | 0.43 | 0.08 |
| ExtraTreeClassifier | 0.46 | 0.45 | None | 0.44 | 0.06 |
| AdaBoostClassifier | 0.38 | 0.39 | None | 0.38 | 2.68 |
| SVC | 0.37 | 0.37 | None | 0.34 | 1.57 |
| NearestCentroid | 0.32 | 0.33 | None | 0.18 | 0.05 |
| BernoulliNB | 0.31 | 0.32 | None | 0.15 | 0.07 |
| DummyClassifier | 0.31 | 0.31 | None | 0.30 | 0.05 |
| GaussianNB | 0.29 | 0.30 | None | 0.25 | 0.04 |

- **Testing dataset**

# Deep Learning - Results

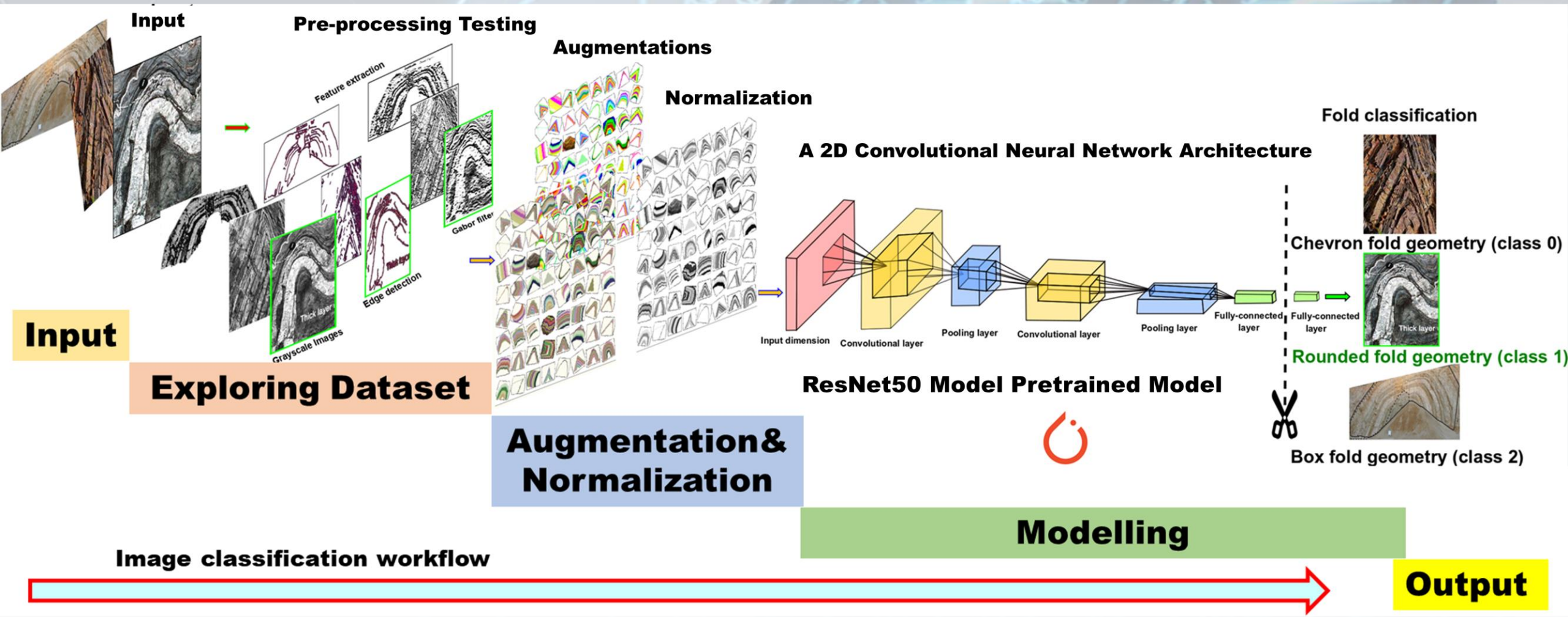


**ResNet50 Pretrained Model Accuracy over 70%**

| Learning | Model | Training | Types of Data | Accuracy (%) | Drive (CPU) - time | Colud (GPU) - time |
|---|---|---|---|---|---|---|
| Shallow | Random Forest | Untrained | Test | 57 | 13min 3s | - |
| | | | Val | 64 | | |
| Deep | ResNet9 | Untrained Greyscale | Test | 61.7 | 2h 12min 43s | 20min 35s |
| | | | Val | 55.7 | | |
| | | Untrained Coloured | Test | 69 | 2h 2min 14s | 22min 45s |
| | | | Val | 60 | | |
| Transfer | ResNet34 | Untrained | Test | 42.6 | 2h 4min 54s | 25min 15s |
| | | | Val | 45 | | |
| | | Pretrained | Test | 63 | 2h 7min 25s | 25min 9s |
| | | | Val | 60 | | |
| | ResNet50 | Untrained | Test | 33.8 | 3h 52min 48s | 3h 27min 2s |
| | | | Val | 45 | | |
| | | Pretrained | Test | **70.6** | 3h 14min 58s | 30min 35s |
| | | | Val | **62** | | |
| | ResNet101 | Untrained | Test | 39.7 | 3h 8min 15s | 32min 11s |
| | | | Val | 38.9 | | |
| | | Pretrained | Test | 61.7 | 4h 58min 34s | 44min 9s |
| | | | Val | 61 | | |
| | ResNet152 | Untrained | Test | 33.8 | 3h 33min 1s | 34min 7s |
| | | | Val | 36.7 | | |
| | | Pretrained | Test | 66.2 | 6h 1min 48s | 58min 6s |
| | | | Val | 61.3 | | |

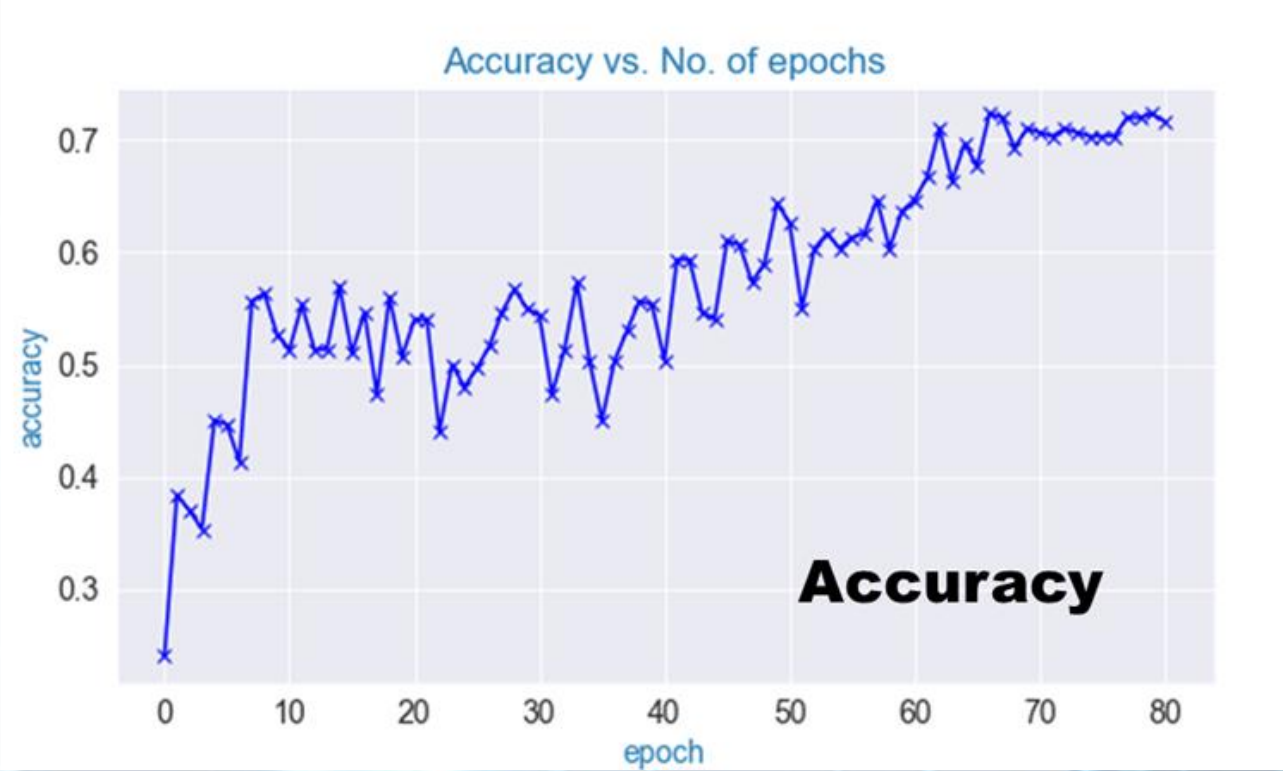
# Transfer Learning workflow

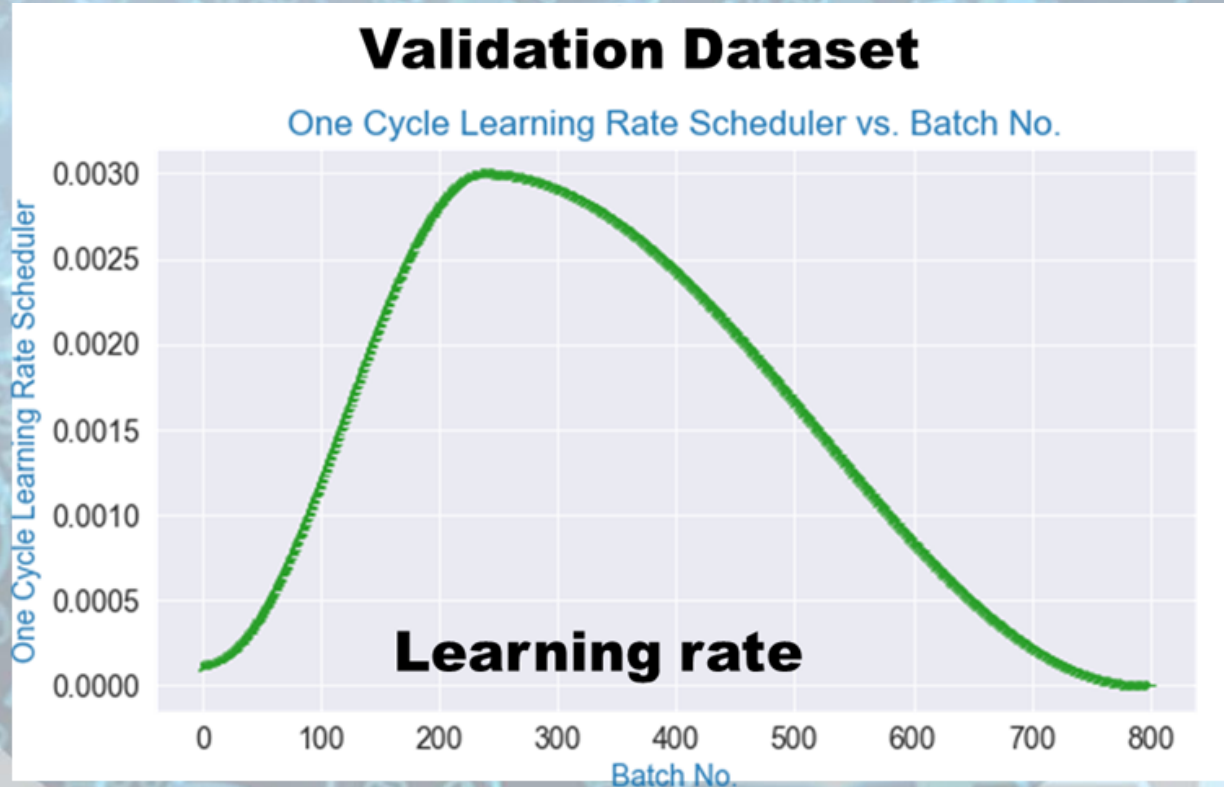




# Model Evaluation

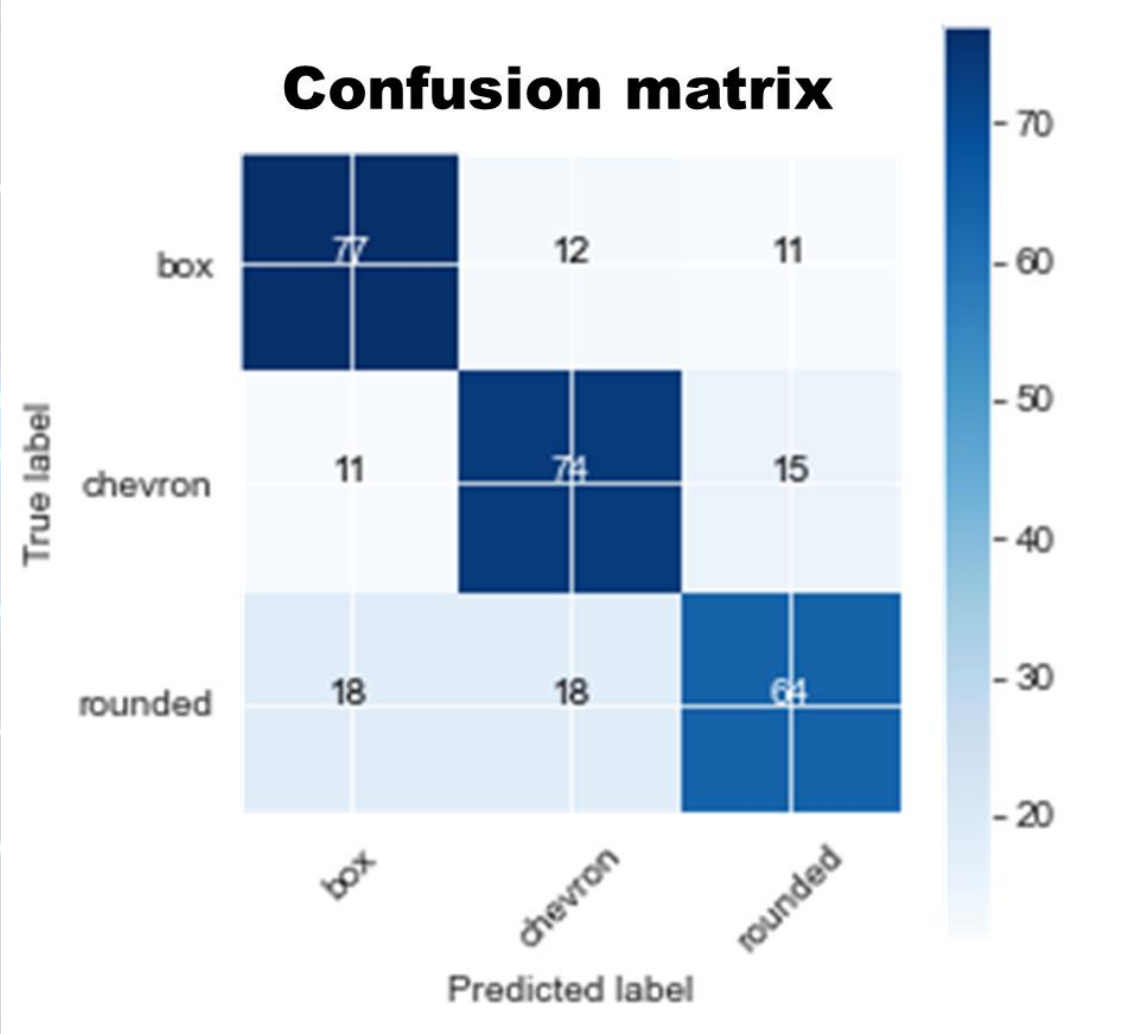


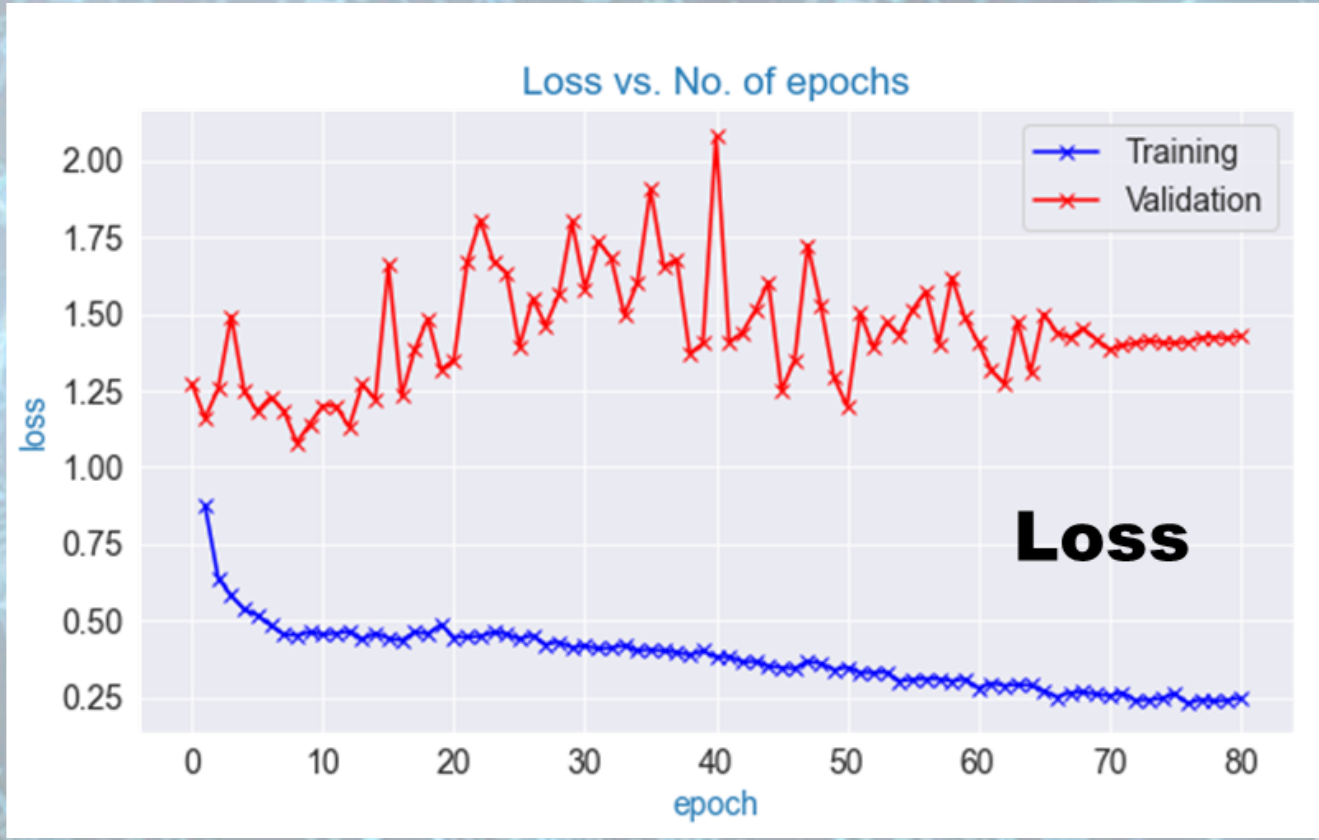


# Model Evaluation

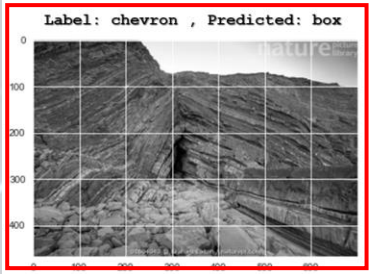


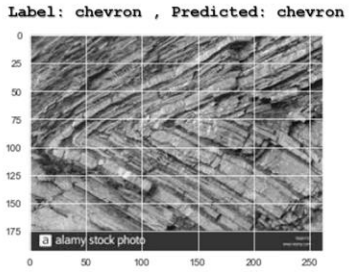


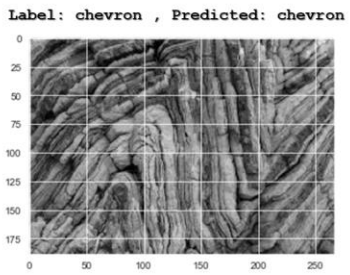



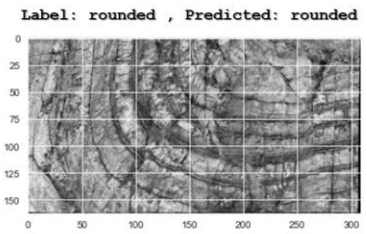
# Classification Examples

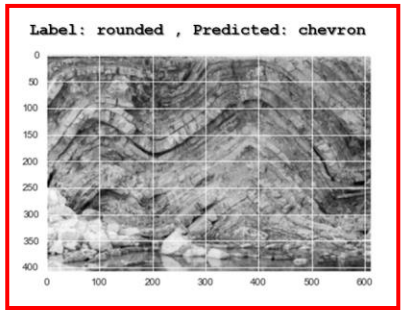


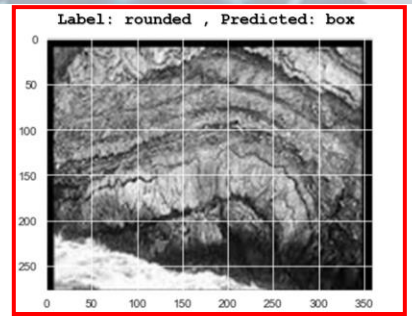


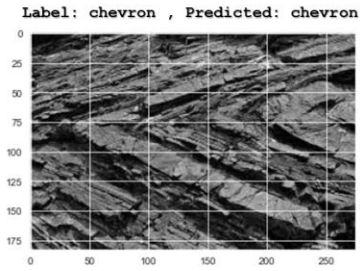



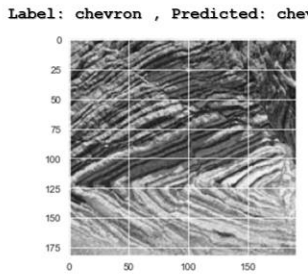



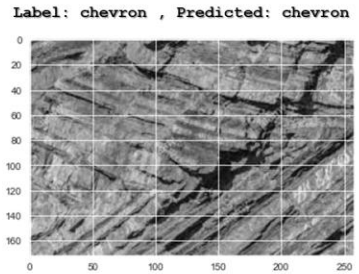



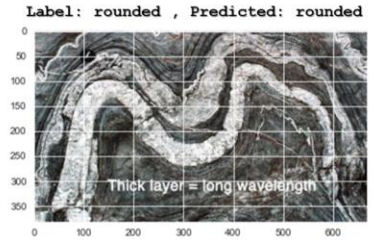



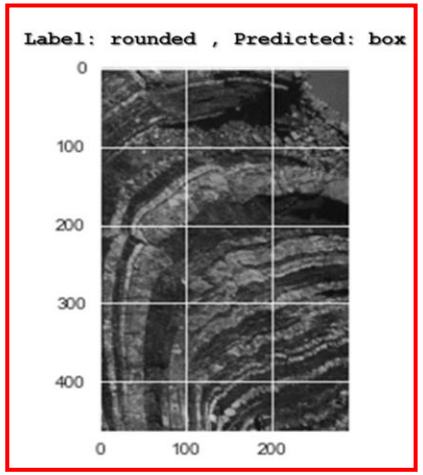



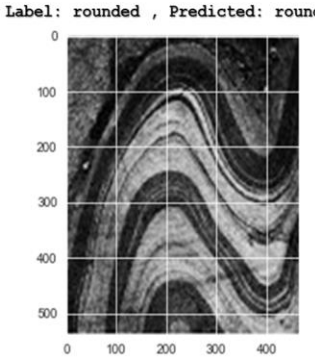



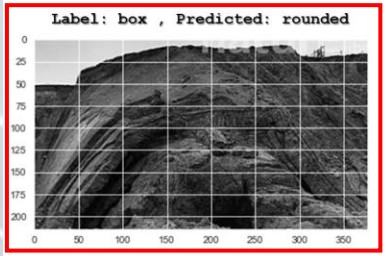



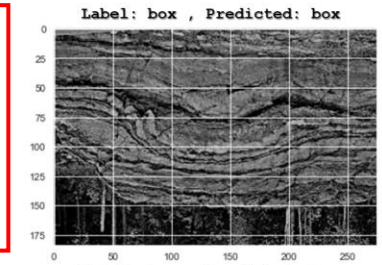



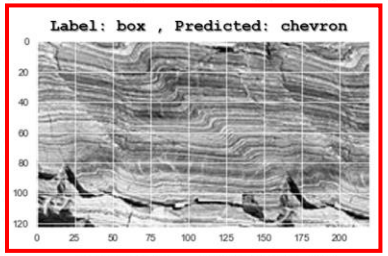



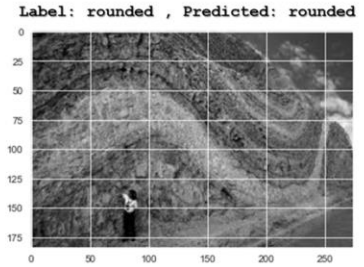



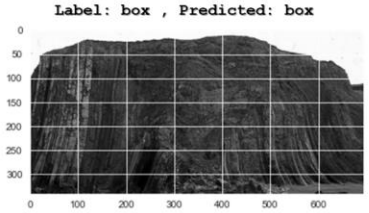



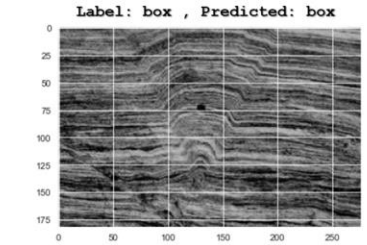



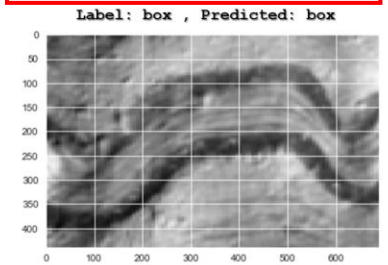



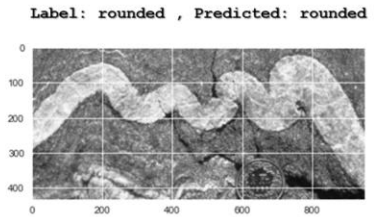



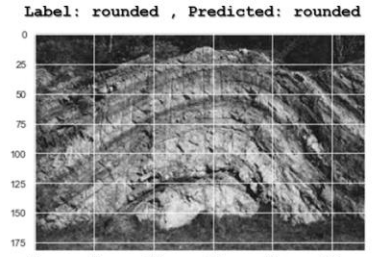



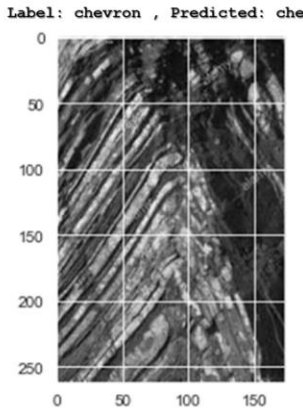



# Conclusions

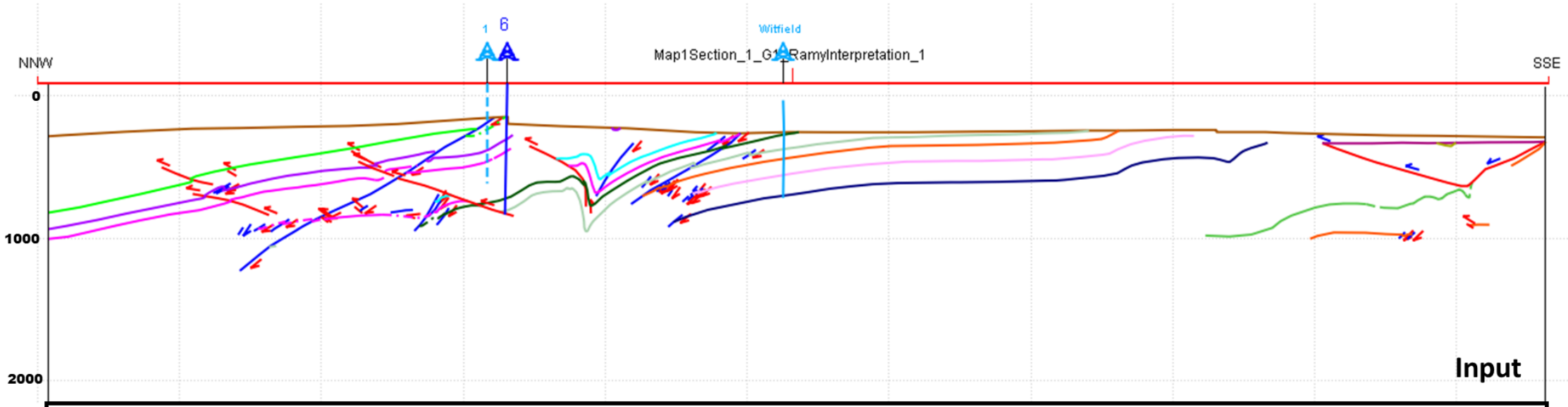


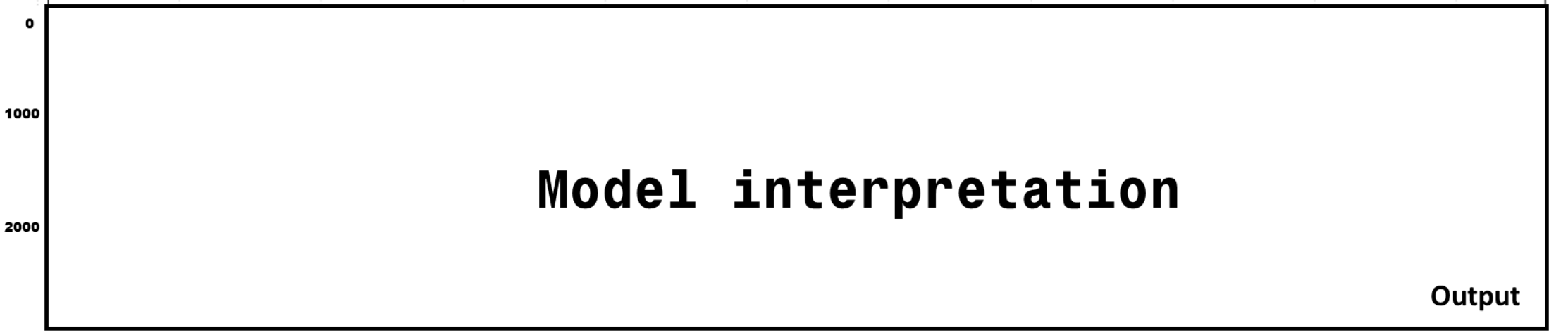
- We proposed modelled **data**, augmentation and normalization as methods to overcome geosciences data limitations.
- **Shallow learning** and feature extraction can be made prior to any deep learning study.
- **Convolutional Neural Networks** (CNNs) can help addressing geosciences classification problems.
- **Deep transfer learning** doing better in this case study.
- **Resnet50** model record the higher accuracy in our study.
- Can deductions be drawn from machine and deep learning studies?

# Future work



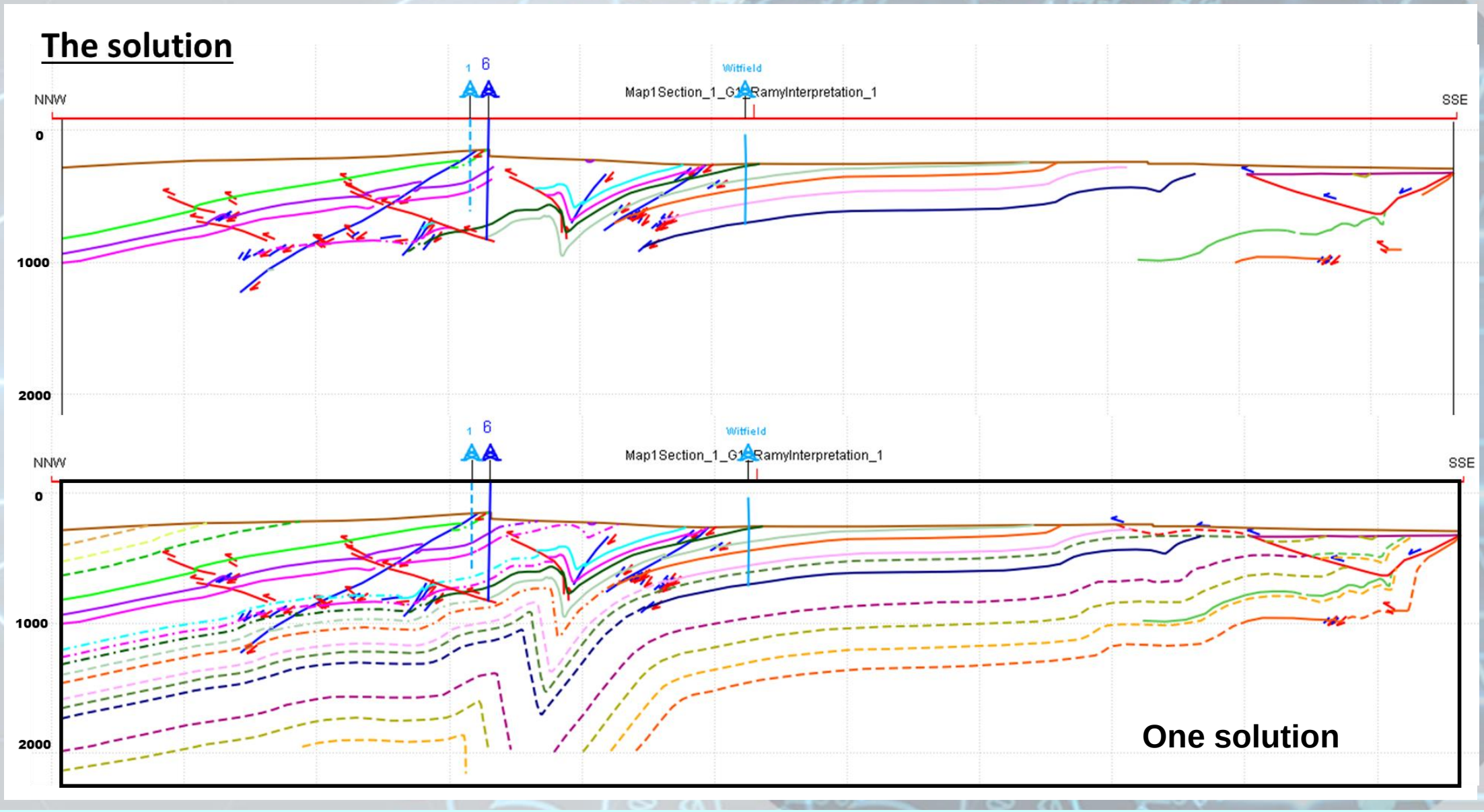
## Example of Test data



# Future work

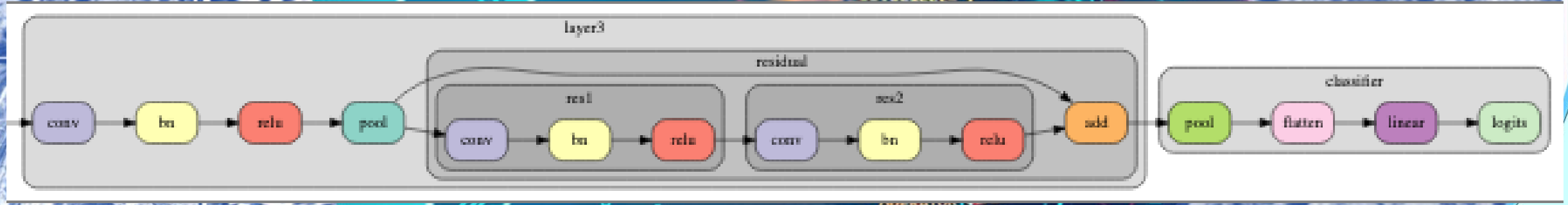



The solution
1
6
Witfield
Map1Section_1_G1RamyInterpretation_1
NNW
SSE
0
1000
2000
One solution


r.abdallah.18@abdn.ac.uk

Natural Environment Research Council

Centre for Doctoral Training (CDT) in Oil and Gas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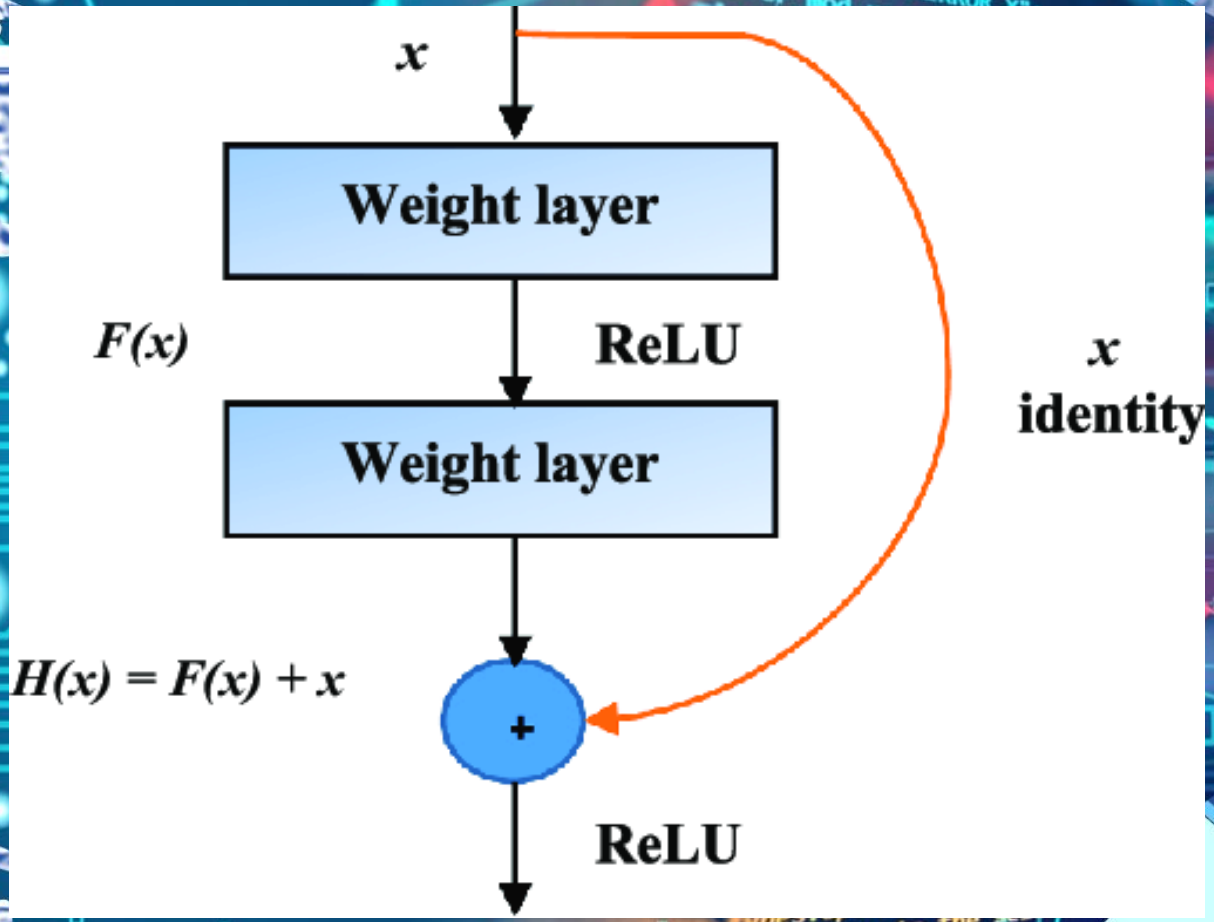


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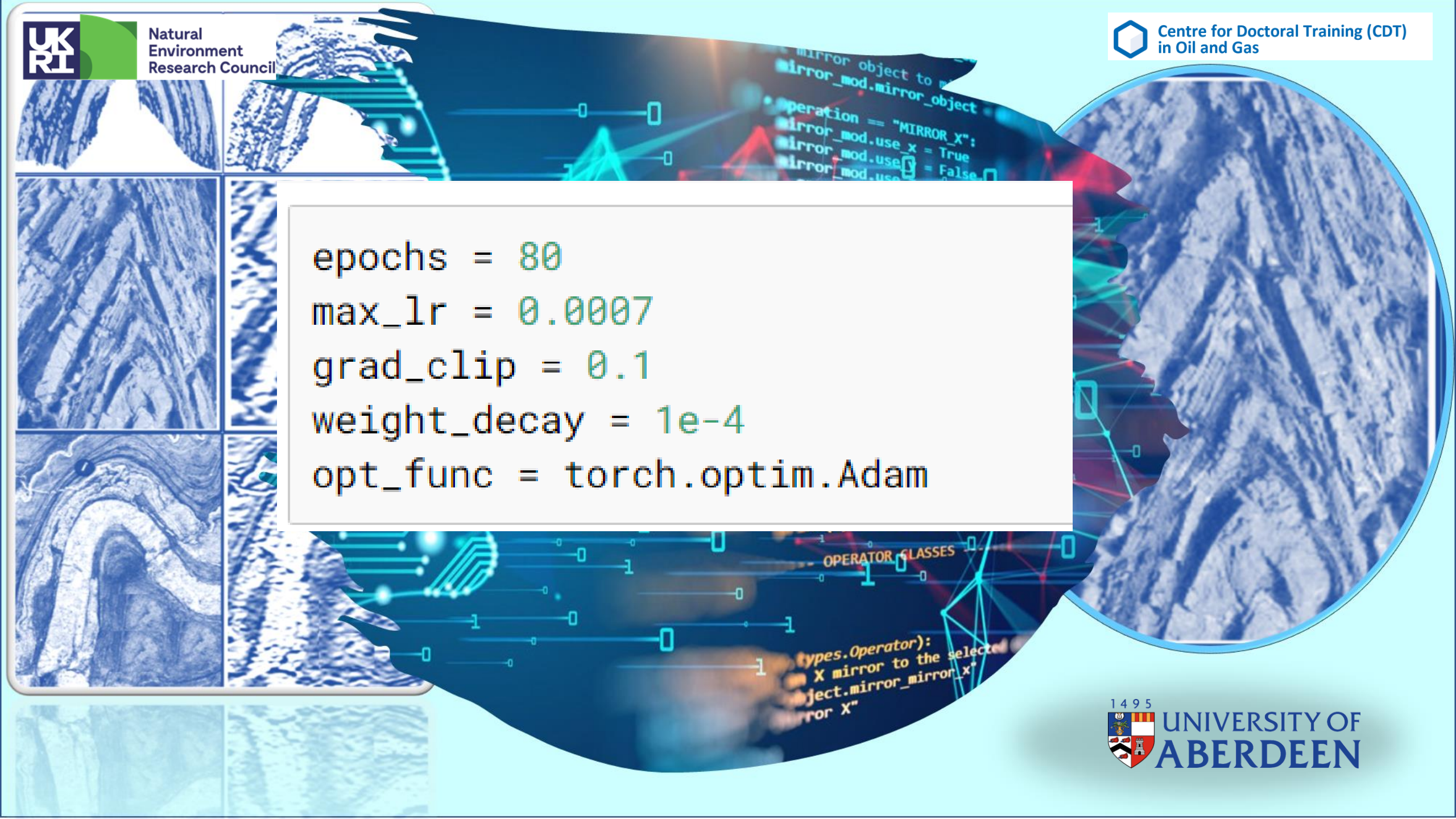
```
# Data transforms (normalization & data augmentation) # tt.RandomCrop(64, padding=4, padding_mode='reflect')
stats = ((0.485, 0.456, 0.406), (0.229, 0.224, 0.225))
randomrotate = 10 # 0.175 rad
train_tfms = tt.Compose([tt.Resize((image_size, image_size)),
                         tt.RandomCrop(image_size, padding=4, padding_mode='reflect'),
                         tt.Resize(image_size),
                         tt.CenterCrop(image_size),
                         tt.RandomHorizontalFlip(),
                         tt.RandomVerticalFlip(),
                         tt.Pad((2, 5, 0, 5)),
                         #tt.RandomRotation(randomrotate),
                         tt.RandomAffine(0, translate=(0.4, 0.5)),
                         tt.RandomRotation(randomrotate, resample=PIL.Image.NEAREST, expand=False, center=(40,
                         #tt.RandomResizedCrop(256, scale=(0.5,0.9), ratio=(1, 1)),
                         tt.ColorJitter(brightness=0.1, contrast=0.1, saturation=0.1, hue=0.1), ##
                         tt.ToTensor(),
                         tt.Normalize(*stats,inplace=True)])
valid_tfms = tt.Compose([tt.Resize((image_size, image_size)), tt.ToTensor(), tt.Normalize(*stats)])

test_tfms = tt.Compose([tt.Resize((image_size, image_size)), tt.ToTensor(), tt.Normalize(*stats)])
```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epochs = 80
max_lr = 0.0007
grad_clip = 0.1
weight_decay = 1e-4
opt_func = torch.optim.Adam
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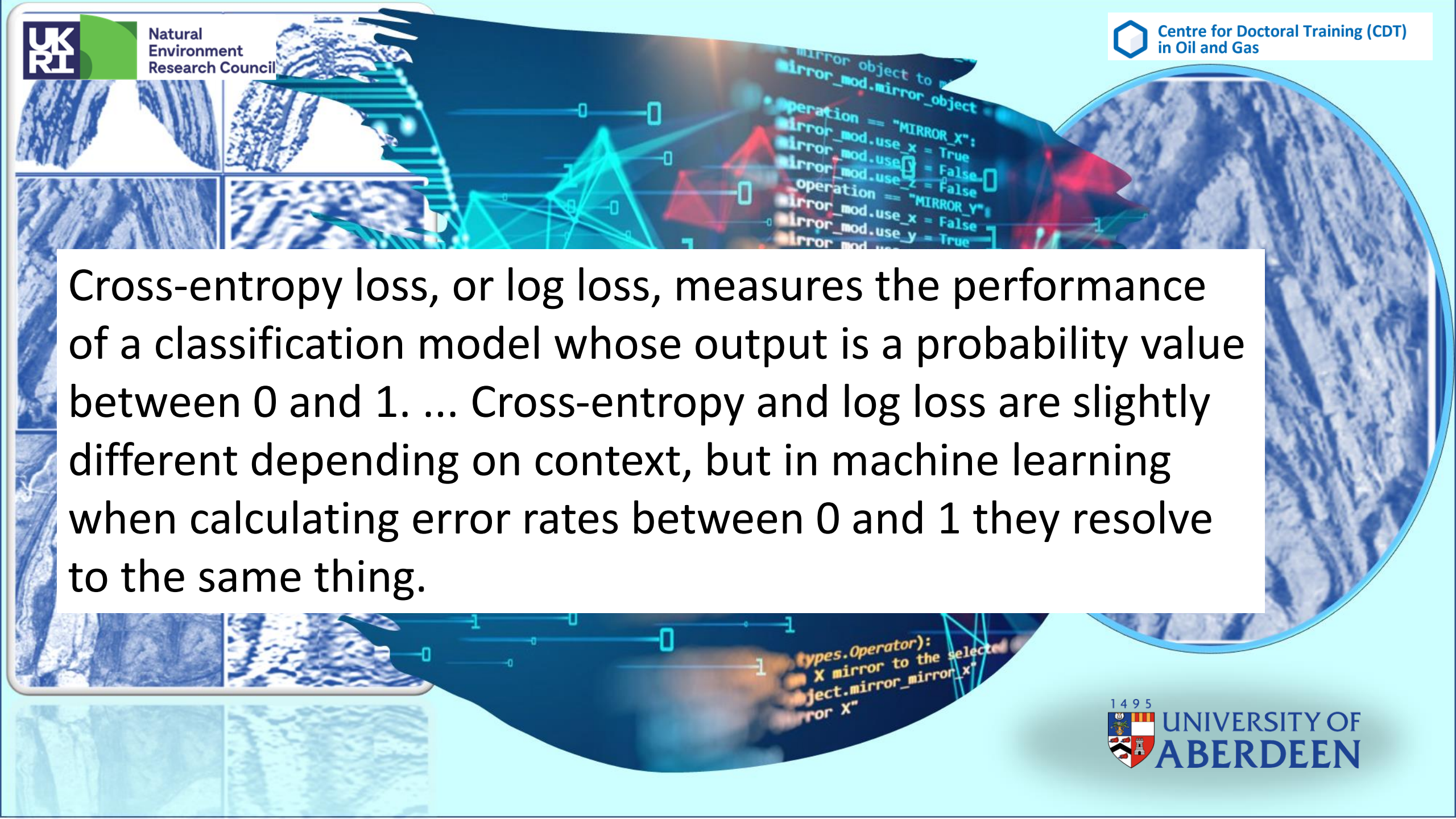
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Cross-entropy loss, or log loss, measures the performance of a classification model whose output is a probability value between 0 and 1. ... Cross-entropy and log loss are slightly different depending on context, but in machine learning when calculating error rates between 0 and 1 they resolve to the same thing.
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mirror_mod.mirror_object
operation == "MIRROR_X":
irror_mod.use_x = True
irror_mod.use_y = False
irror_mod.use_z = False
operation == "MIRROR_Y":
irror_mod.use_x = False
irror_mod.use_y = True
irror_mod.use_z = False
operation == "MIRROR_Z":
irror_mod.use_x = False
irror_mod.use_y = False
irror_mod.use_z = True
selection at the end -ad
_ob.select= 1
er_ob.select=1
ntext.scene.objects.acti
("Selected" + str(modifie
irror_ob.select = 0
bpy.context.selected_ob
ata.objects[one.name].se
int("please select exact
OPERATOR CLASSES
types.Operator):
X mirror to the selected
ject.mirror_mirror_x"
ror X"
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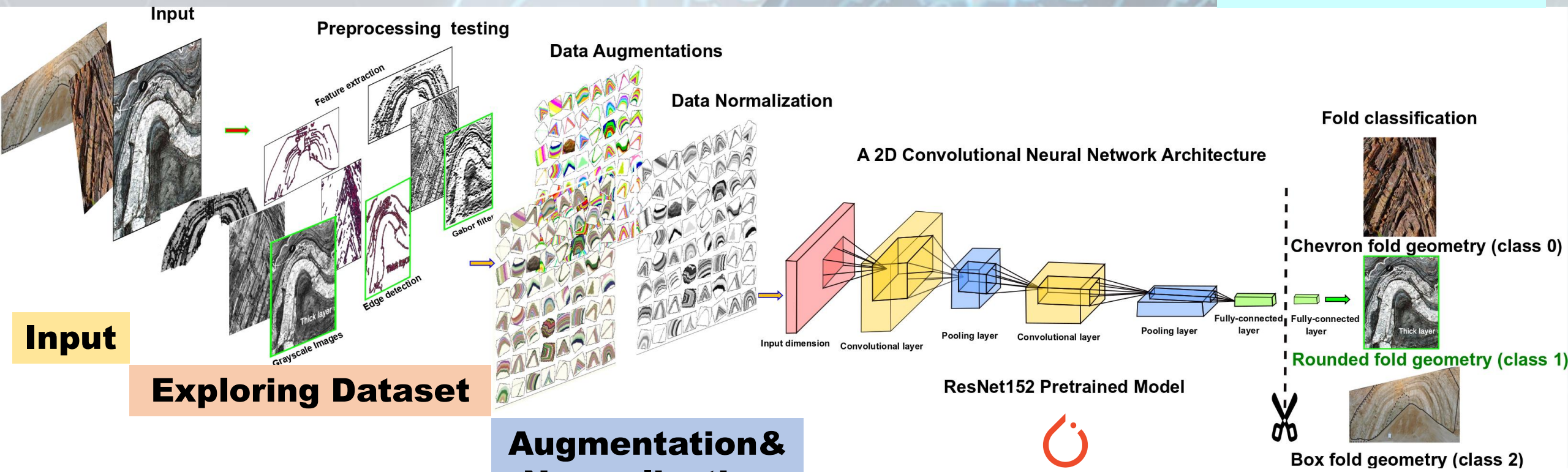
# Transfer Learning workflow



## ResNet50 Model




**Input**

**Exploring Dataset**

**Augmentation& Normalization**

**Modelling**

**Image classification workflow**

**Output**