Probing Putative Biomarker Assignments in SEM Imagery from BRAILLE Investigations at Lava Beds National Monument (N. CA, USA) Using Machine Learning Tools

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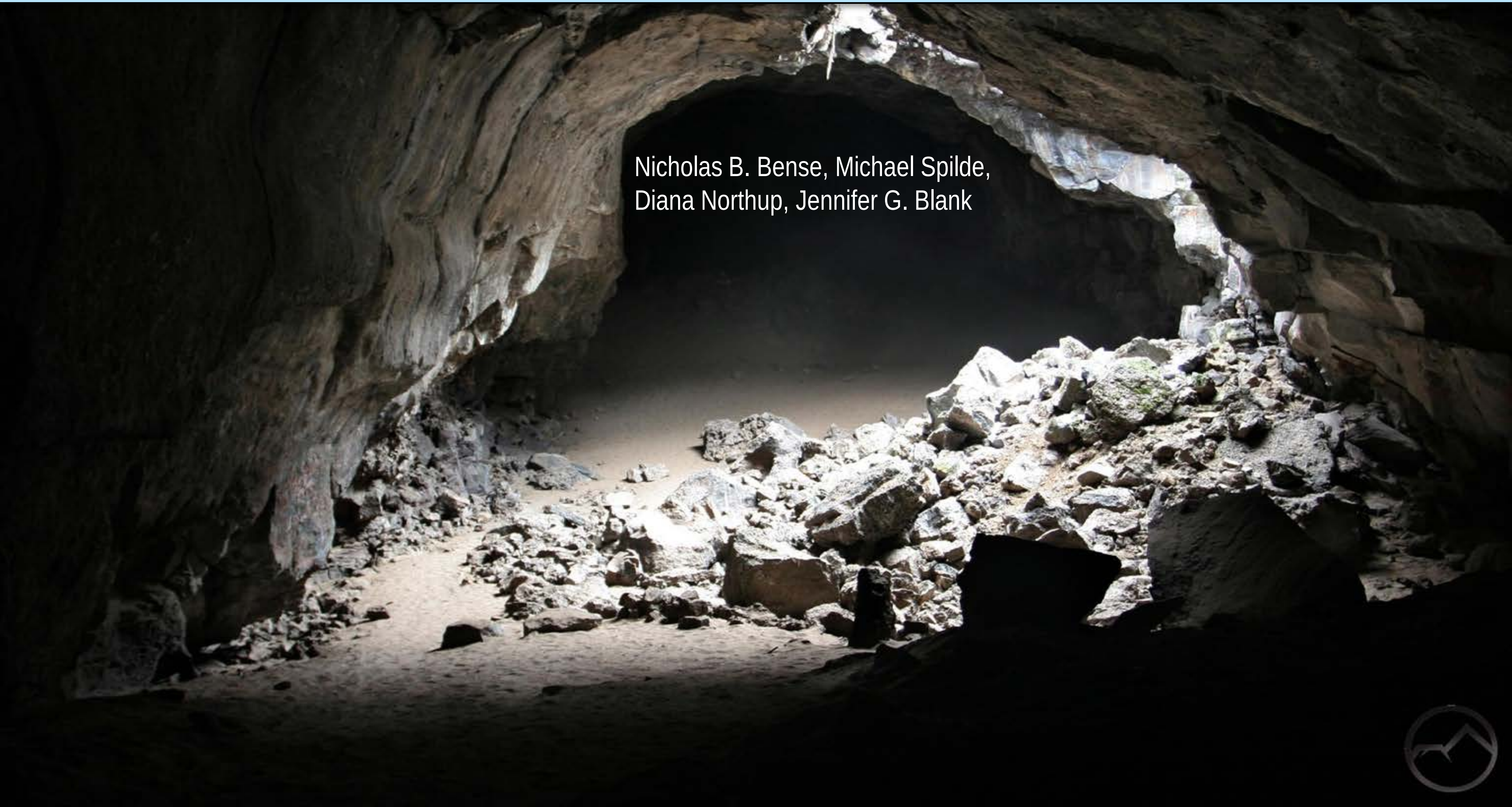
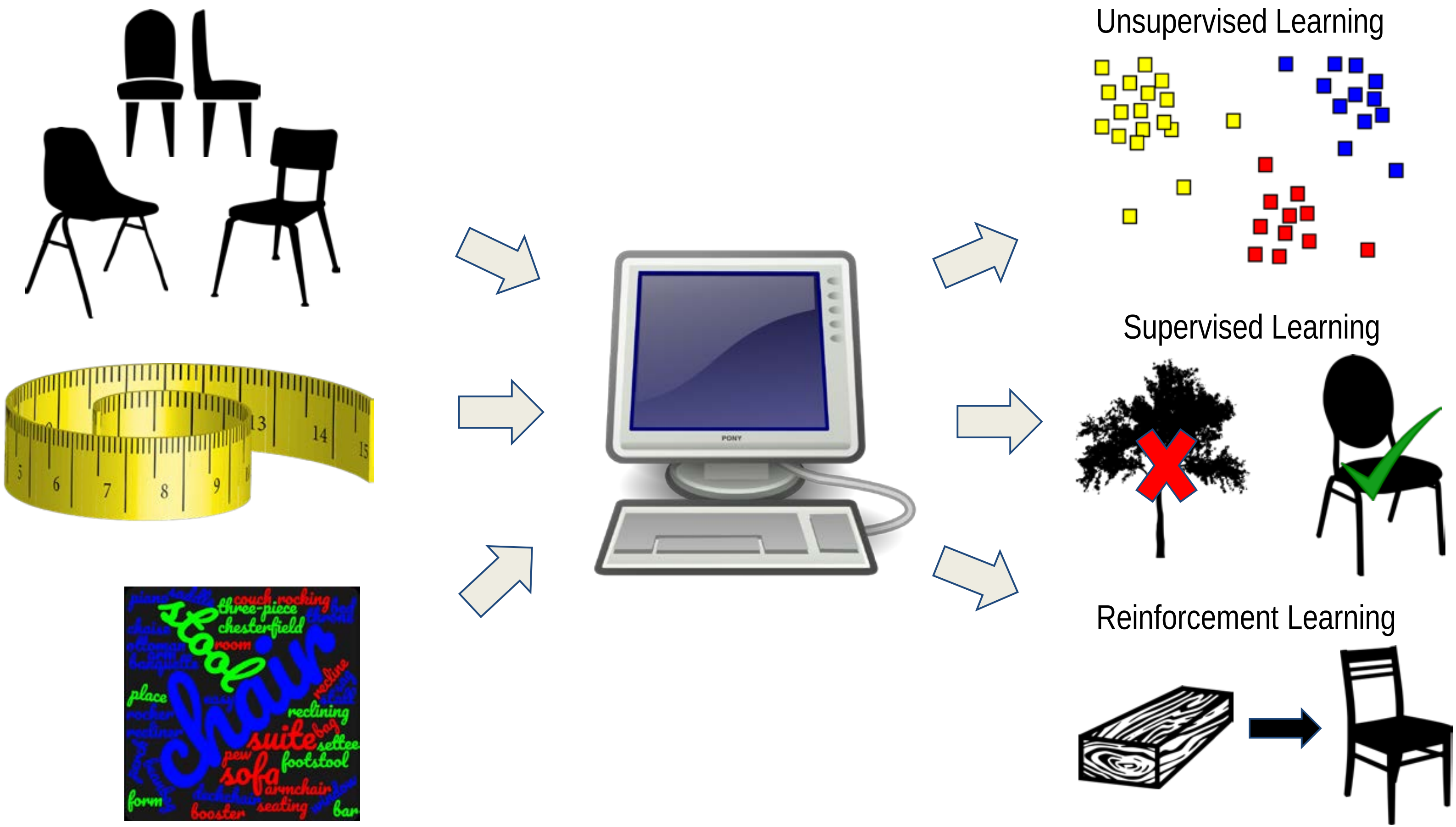
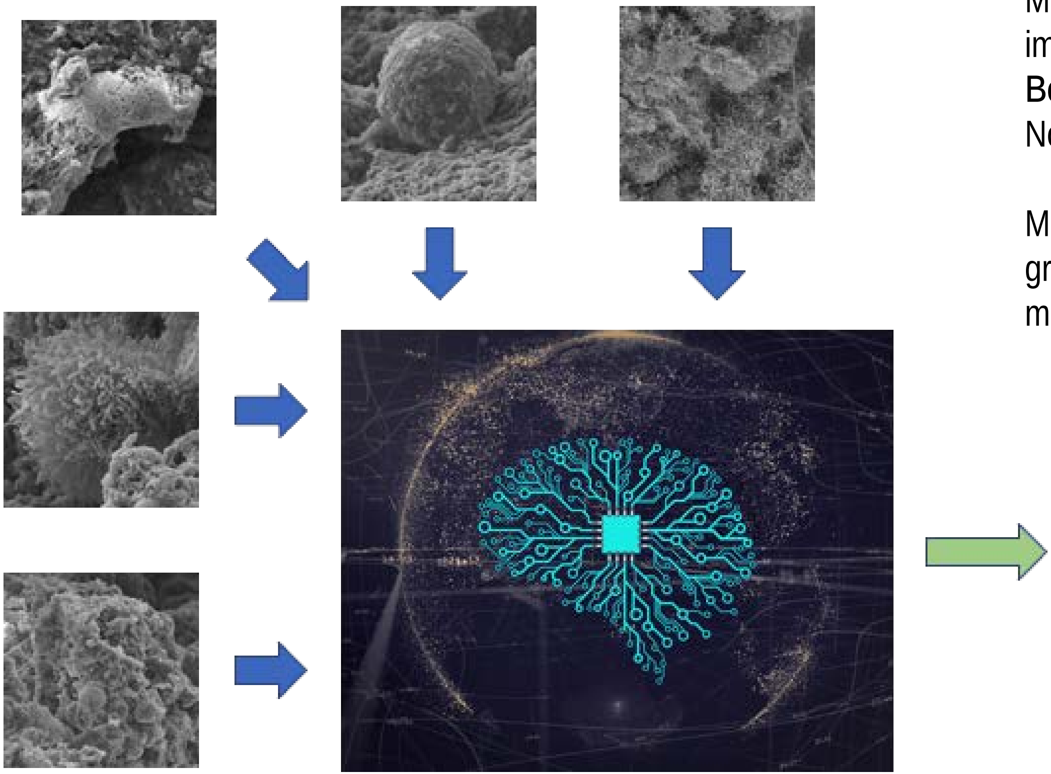


Machine Learning 101



Mineral to Microbe Continuum (MMC) Correlations

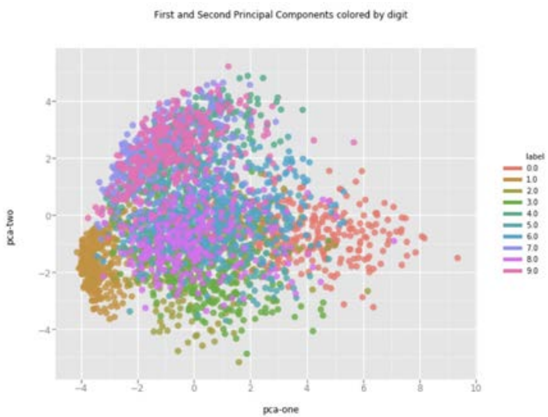


Mineral-Microbe morphologies in SEM images of lava tubes, sampled from **Lava Beds National Monument (LABE)**, Northern CA, USA

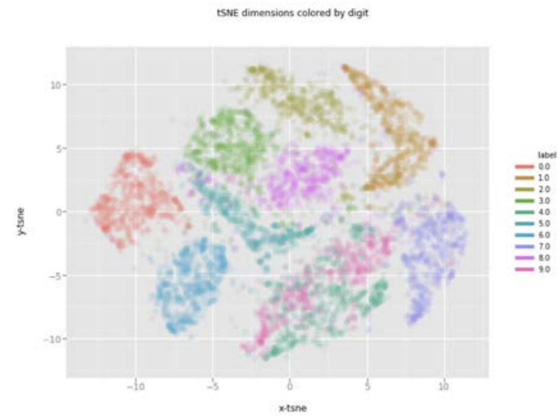
Mineral to Microbe Continuum (MMC): gradient of life activity across mineral/bio-mineral features

Unsupervised Clustering Techniques

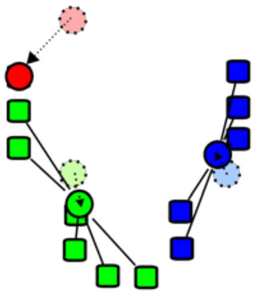
- Principal Component Analysis (PCA)
  - Used to visualize low dimensionality representation of data variance
  - Limited to linear projections
- t-Distributed Stochastic Neighbor Embedding t-SNE)
  - Probabilistic characterization of local structure
  - Prevents low dimensional “crowding problem”
  - Well suited for visualization of high-dimensionality
- K-Means Clustering
  - Optimizes grouping of data into user specified number of groups (“K”)
  - Reassigns data points to new group means with every round until no changes are made



PCA

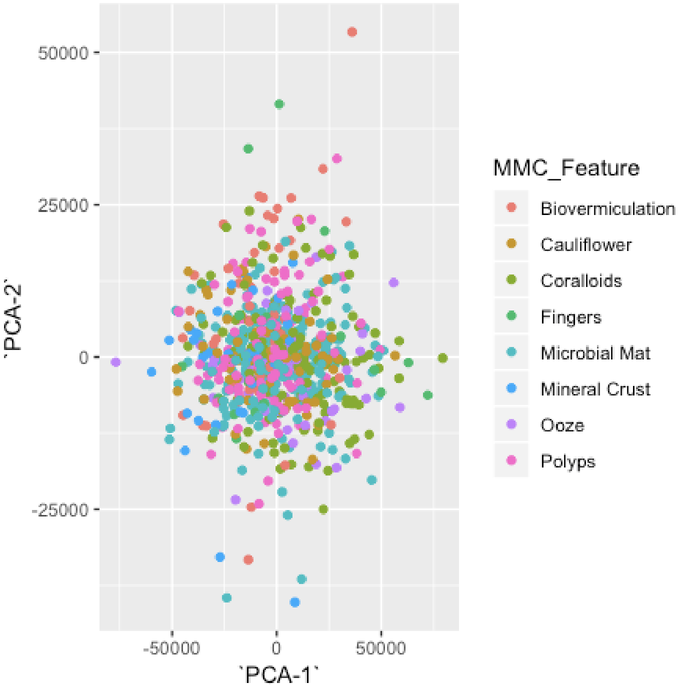


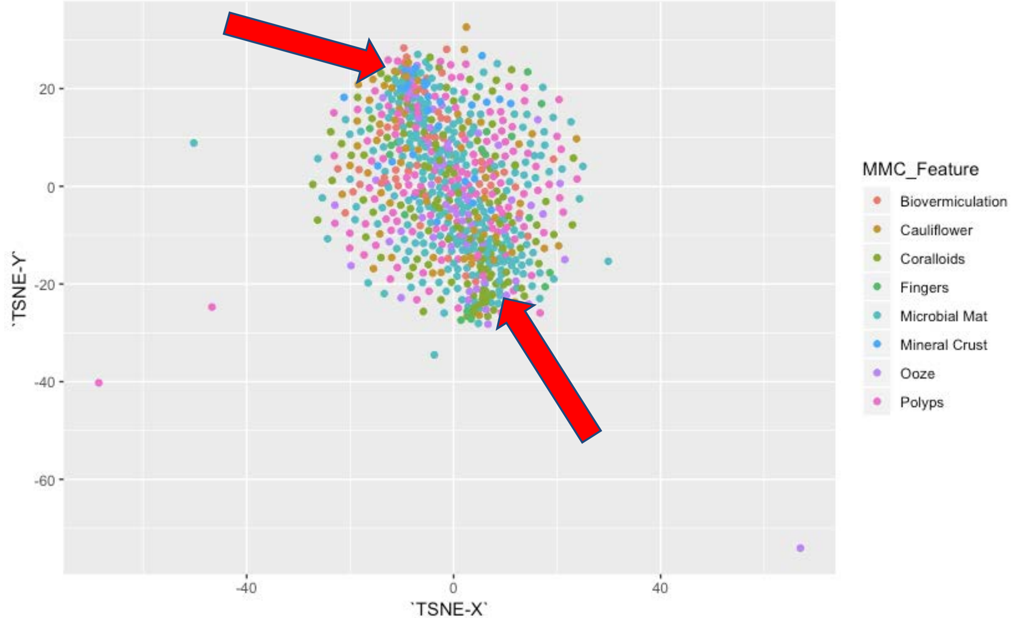
tSNE



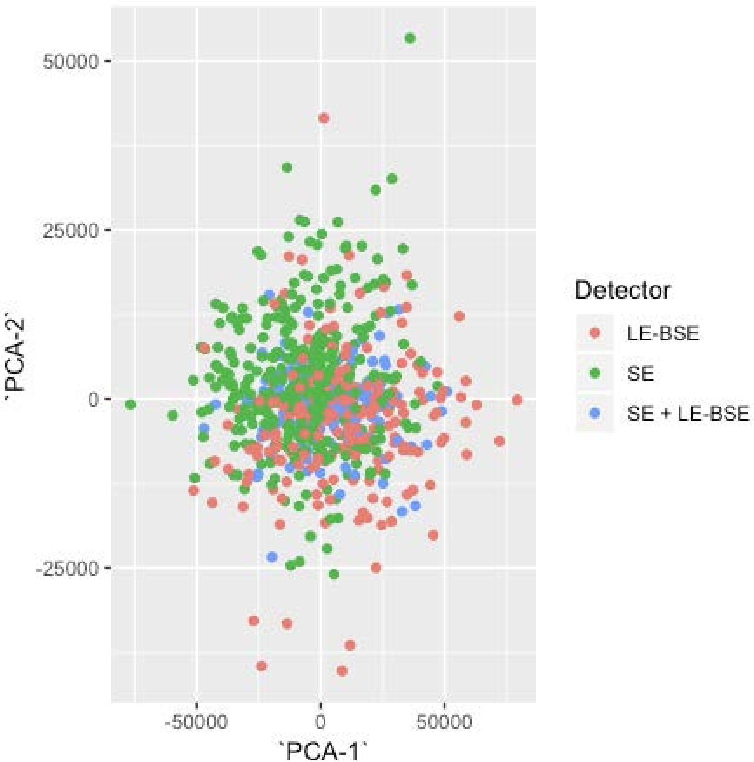
K-Means

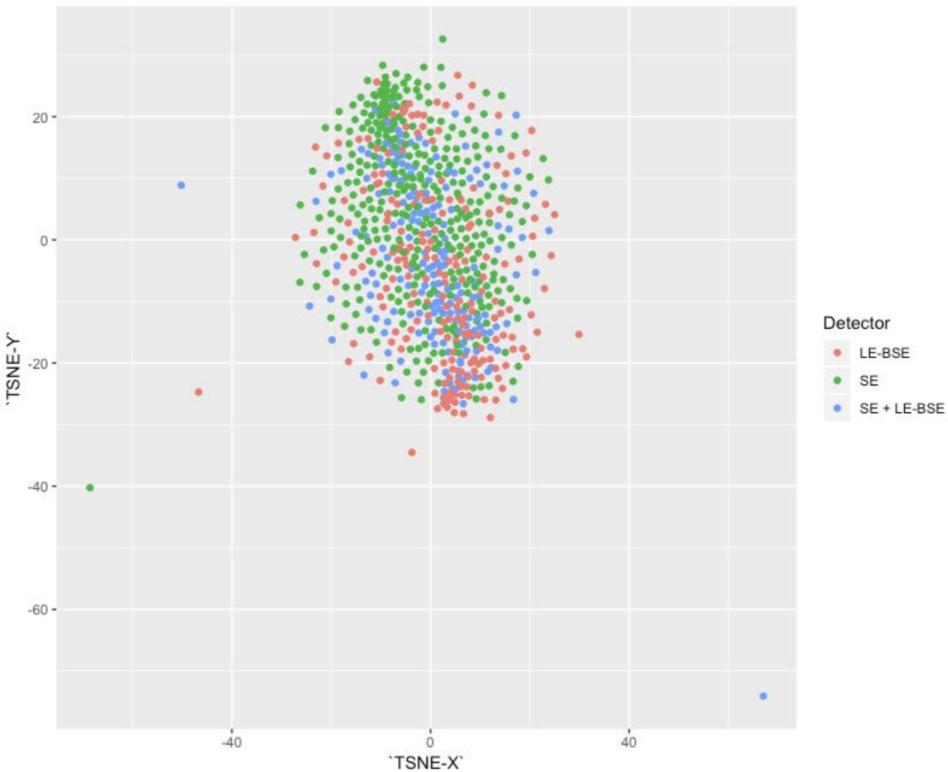
PCA & tSNE – MMC Features (n = 770)



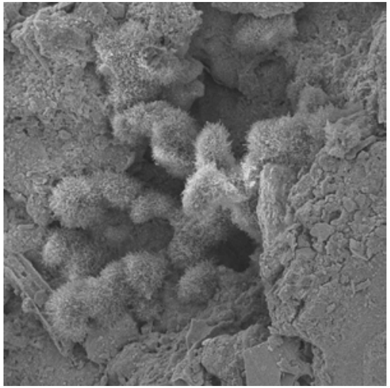


PCA & tSNE – Detector Bias

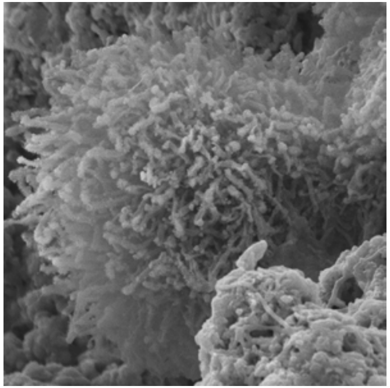




Magnification vs. Morphology



500x



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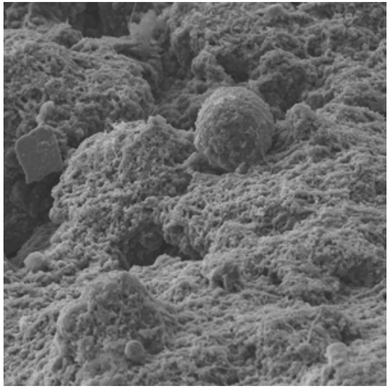

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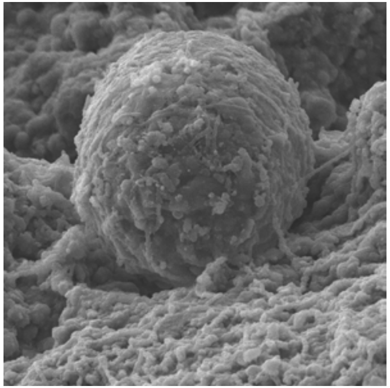
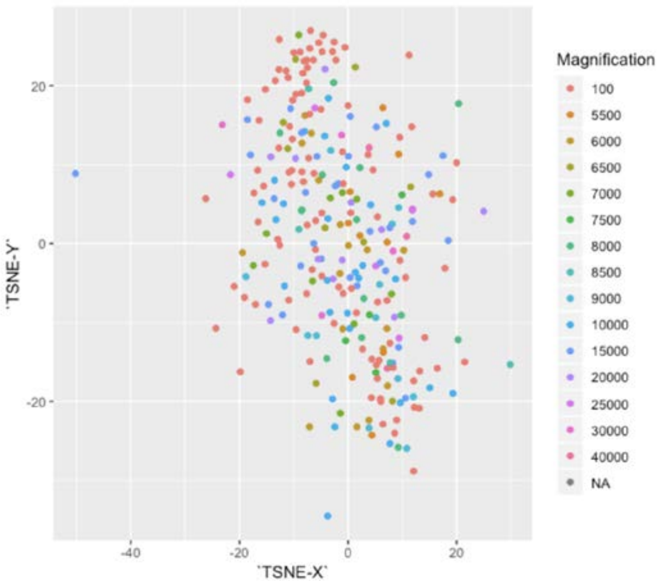


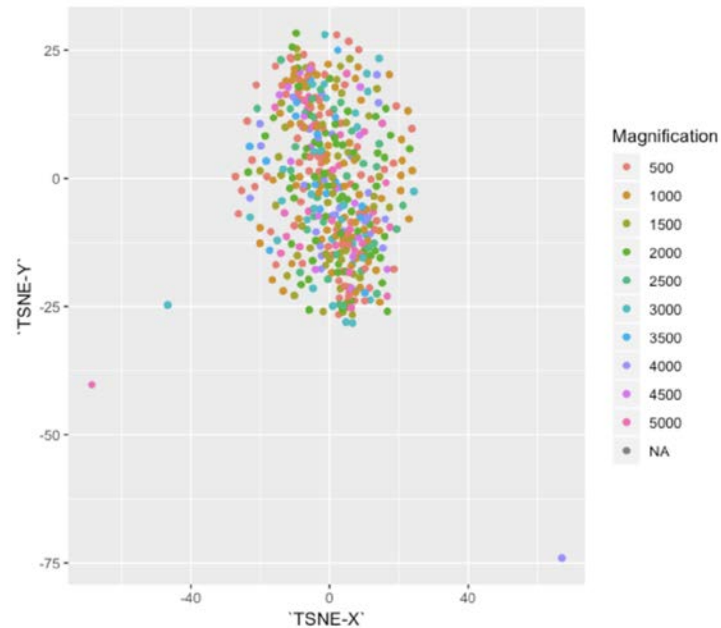
3000x

tSNE – Magnification Plots

Boundary Magnification Ranges (40% of Images)



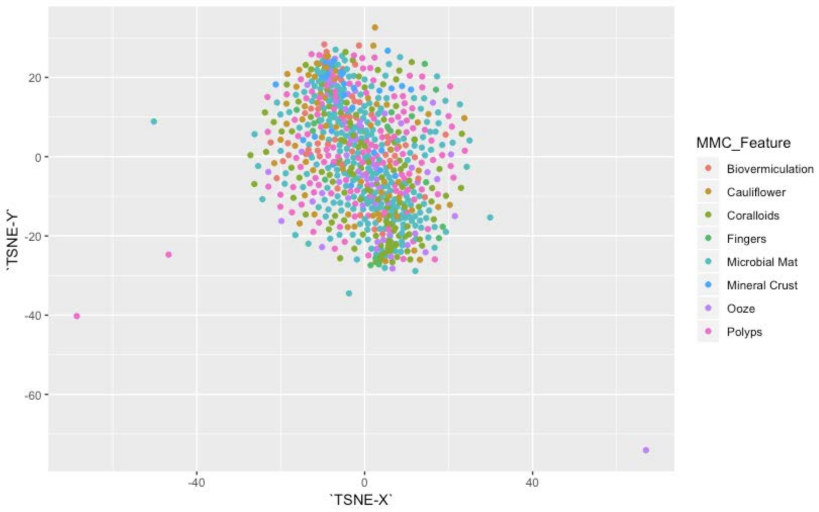
Median Magnification Ranges (60% of Images)



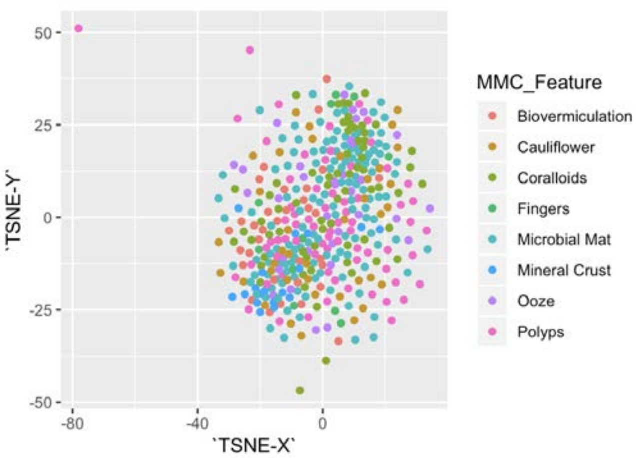
Min. 1st Qu. Median Mean
3rd Qu. Max.
100 500 2000

Magnification tSNE Comparison

All Images (n = 770)

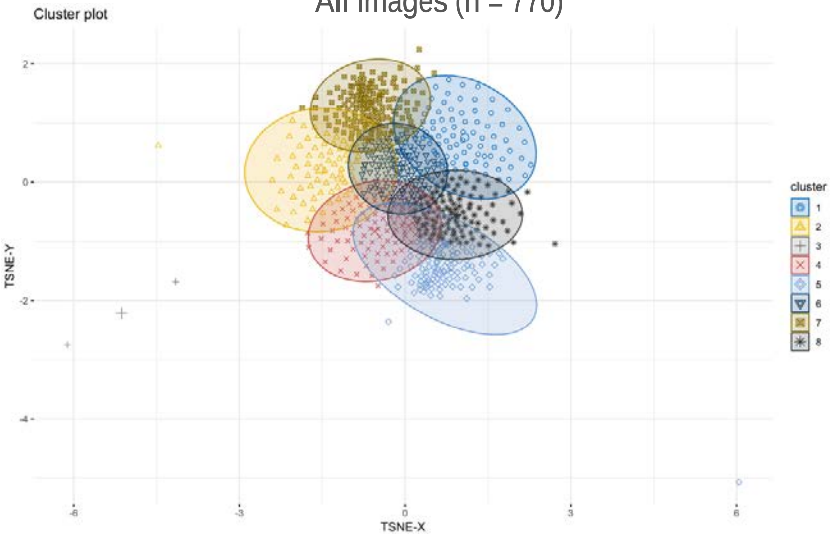


Magnification Subset (n = 401)

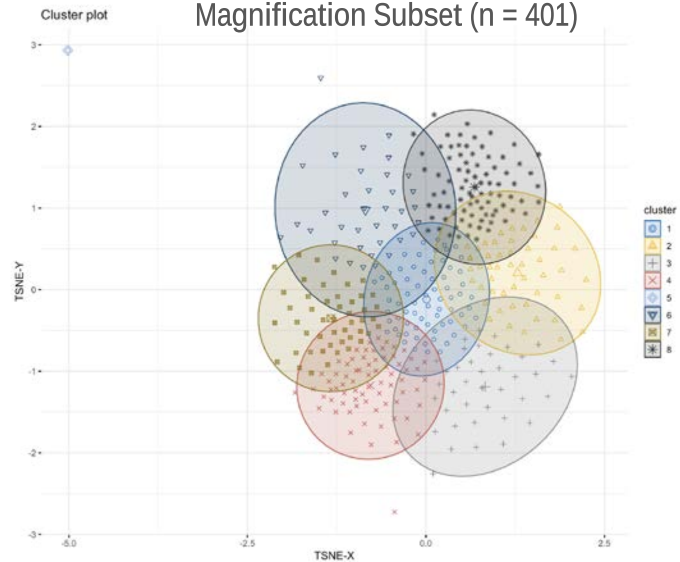


K-Means Clustering on TSNE

All Images (n = 770)



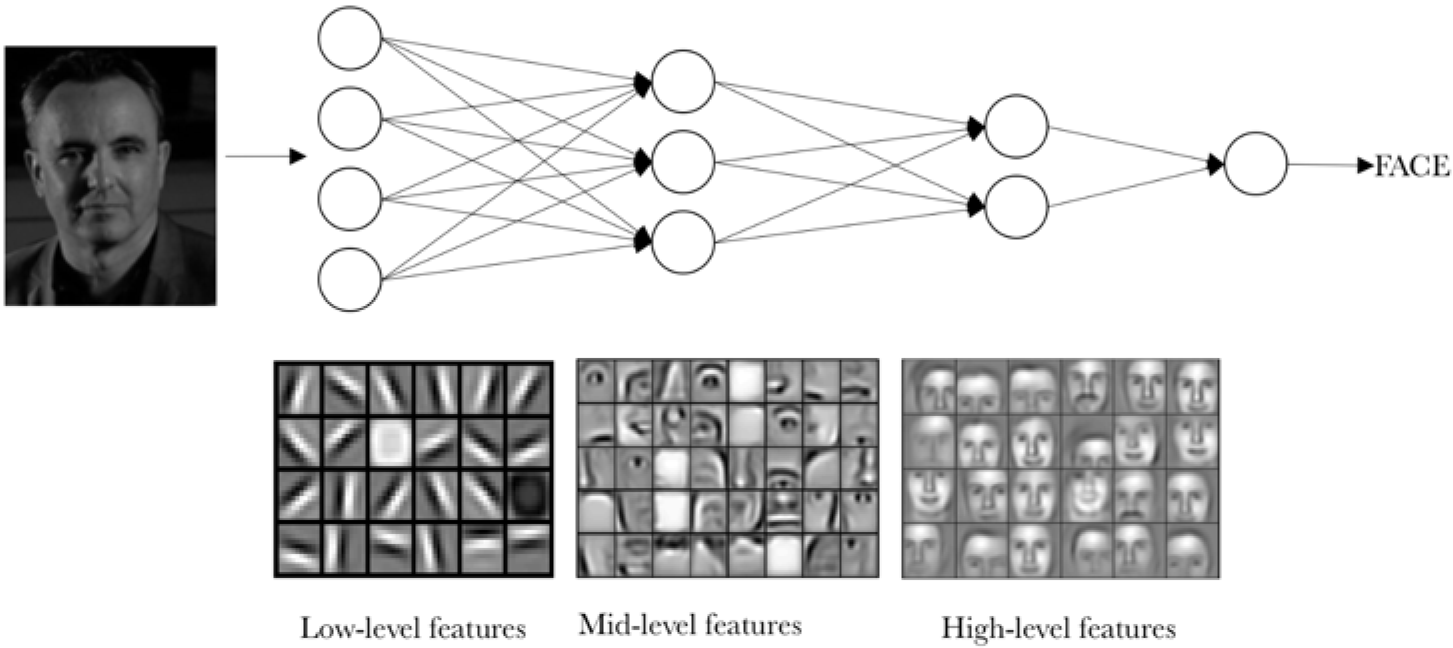
Magnification Subset (n = 401)



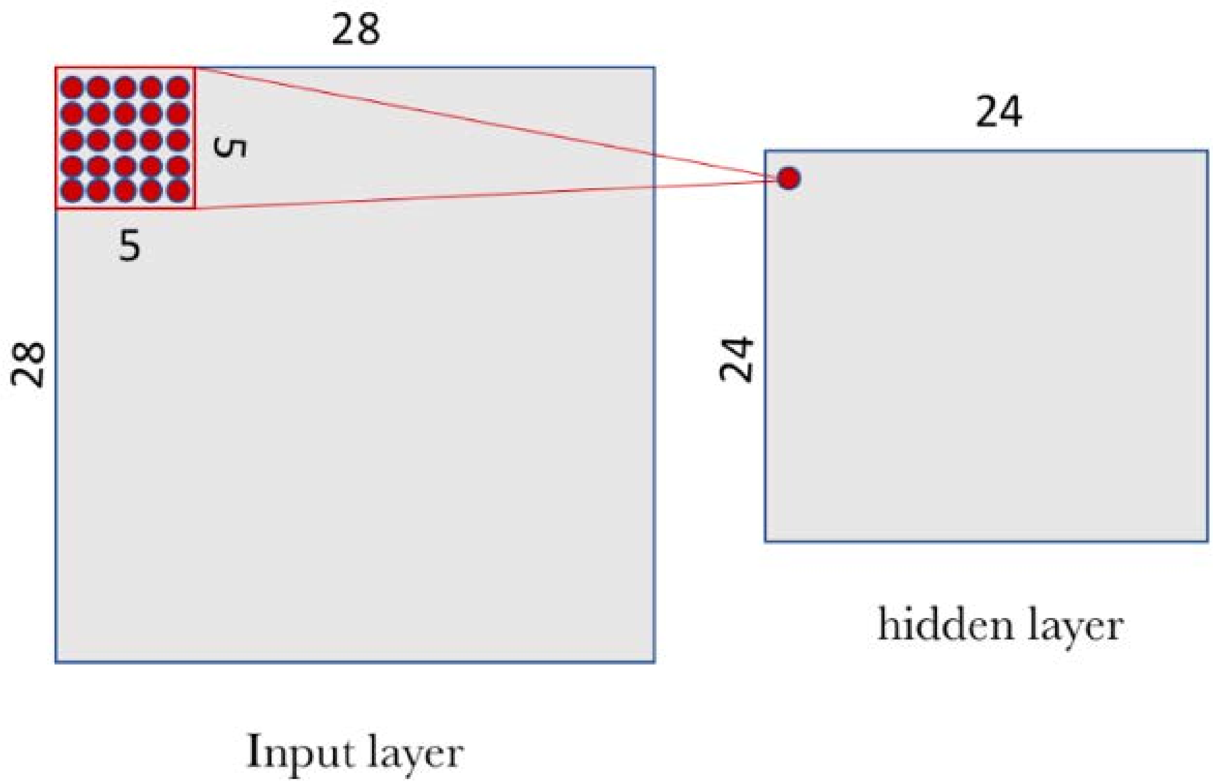
K-Means Cluster vs. MMC Category Corrected Rand Index: **0.006367637**
K-Means Cluster vs. MMC Category Chi-Squared P-Value: **2.721e-07**
MMC vs. TSNE-X + TSNE-Y
MANOVA P-Value: **8.545e-08**
Response TSNE-X P-Value: **0.03237**
Response TSNE-Y P-Value: **1.421e-**

K-Means Cluster vs. MMC Category Corrected Rand Index: **0.02526194**
K-Means Cluster vs. MMC Category Chi-Squared P-Value: **7.529e-08**
MMC vs. TSNE-X + TSNE-Y
MANOVA P-Value: **8.177e-07**
Response TSNE-X P-Value: **6.703e-06**

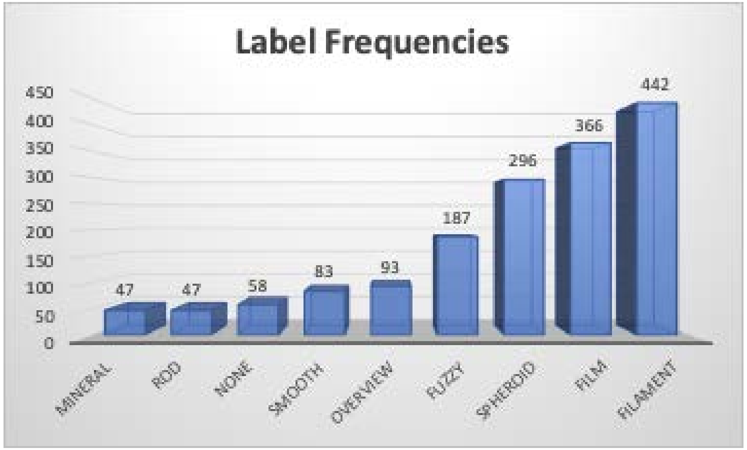
Convolutional Neural Networks (CNNs) for Image Classification



Convolution Layers



CNN Results

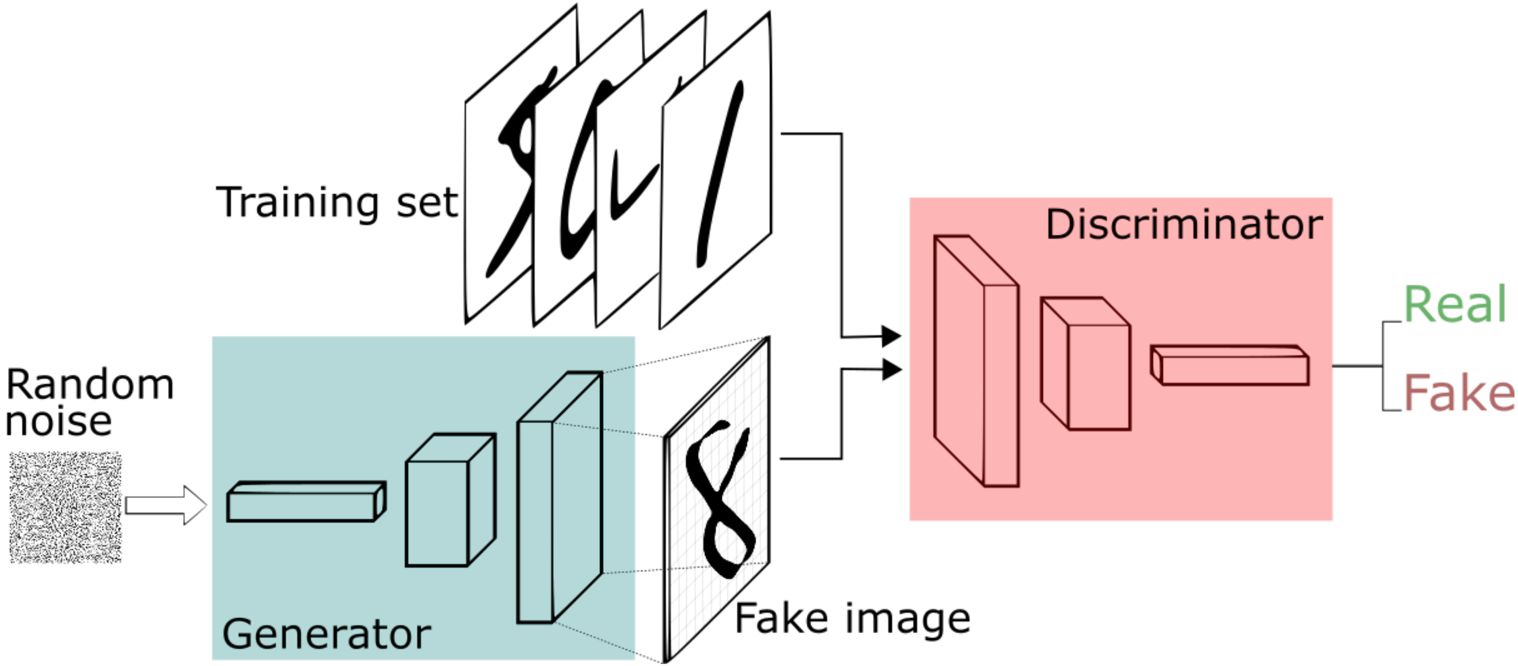


- Binary vs. multiclass vs. multilabel
- Overfitting/Biased Classes
- Possibly insufficient training data

Accuracy

	Binary	Multiclass
Cross-Validation	75%	80%
Hold-Out Testing	55%	50%

Generative Adversarial Networks



Next Steps

- Strengthen supervised classification
  - Generative Adversarial Networks
  - Leverage pre-built models

- Develop methodology for generating unbiased datasets
  - Raster scans
  - Random fields

- Applications
  - Automatically detect microscopic life
  - Correlate morphology with distinct taxonomies
  - Automatically detect biomineralization features/extinct life

Acknowledgements

The Institute of Meteoritics

NASA GeneLab

OPEN SCIENCE FOR LIFE IN SPACE

sky mind