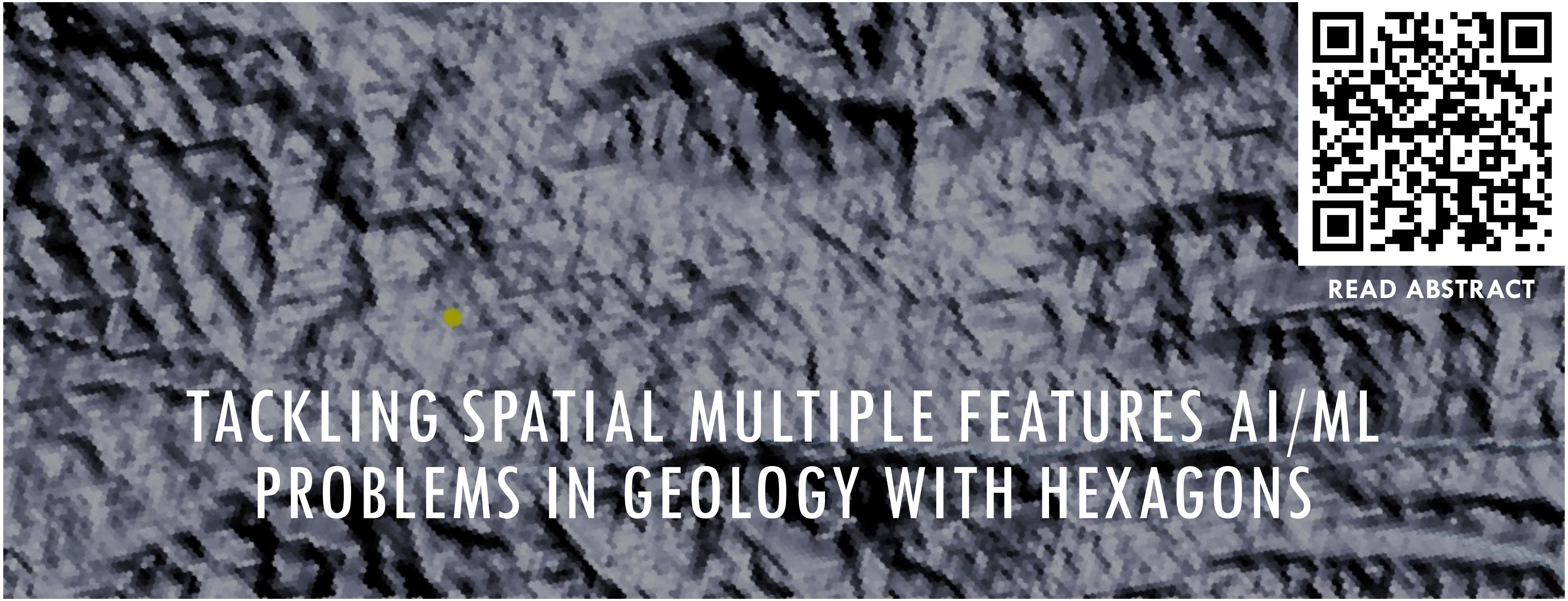

READ ABSTRACT

TACKLING SPATIAL MULTIPLE FEATURES AI/ML PROBLEMS IN GEOLOGY WITH HEXAGONS

SCANDINAVIAN HIGHLANDS

Marie K. Traun, F. Sandø, S. L. Jensen

EGU European Geosciences Union 2025
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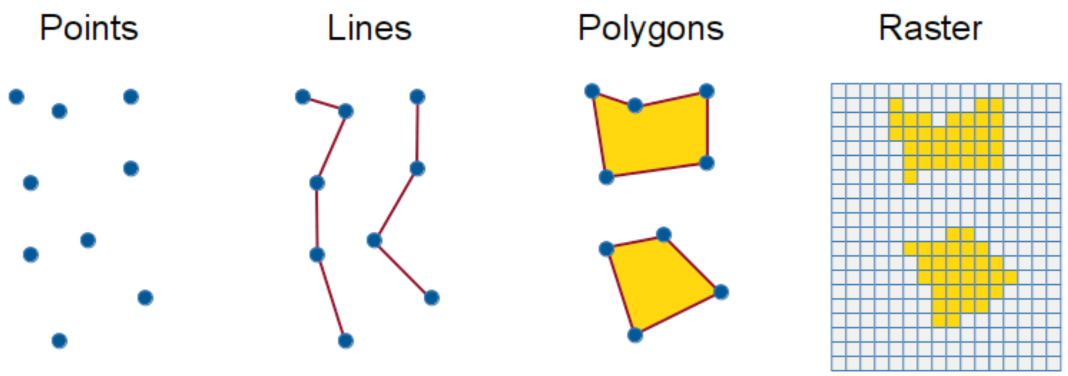
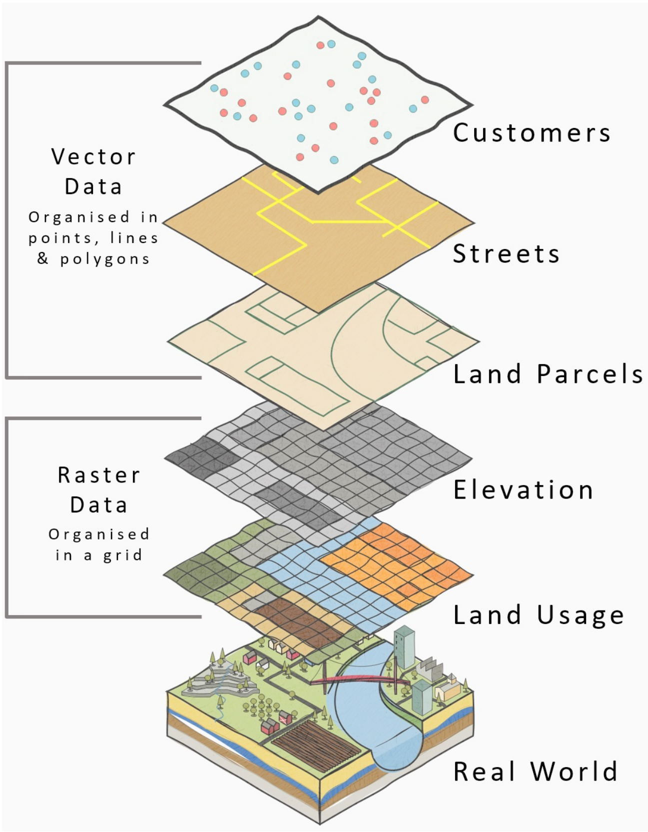
FORMATS, SCALES AND PROJECTIONS

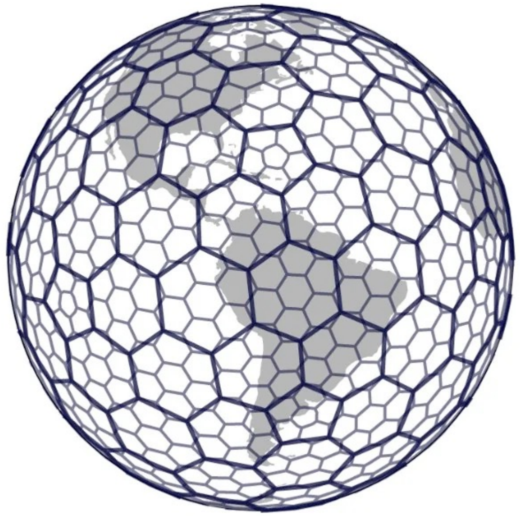
- Difficult to analyse across geological spatial data types and scales
- Requires extensive “regridding”
- Limits insights from multiple feature spatial knowledge in essential applications e.g. raw materials exploration

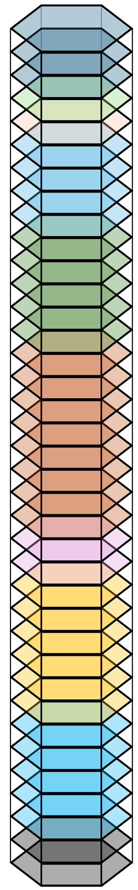




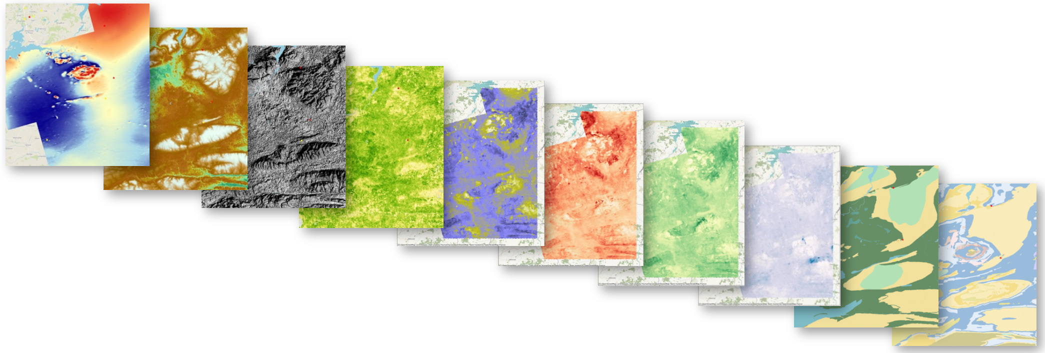
SPATIAL INDEXES AND HEXAGONS

- Convert map data to spatial indexes (H3 Uber)
- Each position on Earth’s surface represented by hexagon cell
- Index ”name” is a 64bit string that contain location, resolution and neighbor/parent relations
- Hexagonized map layers can then be “stacked” to form highly flexible feature tables of a region
- Foundation for data exploration, ML and AI predictions



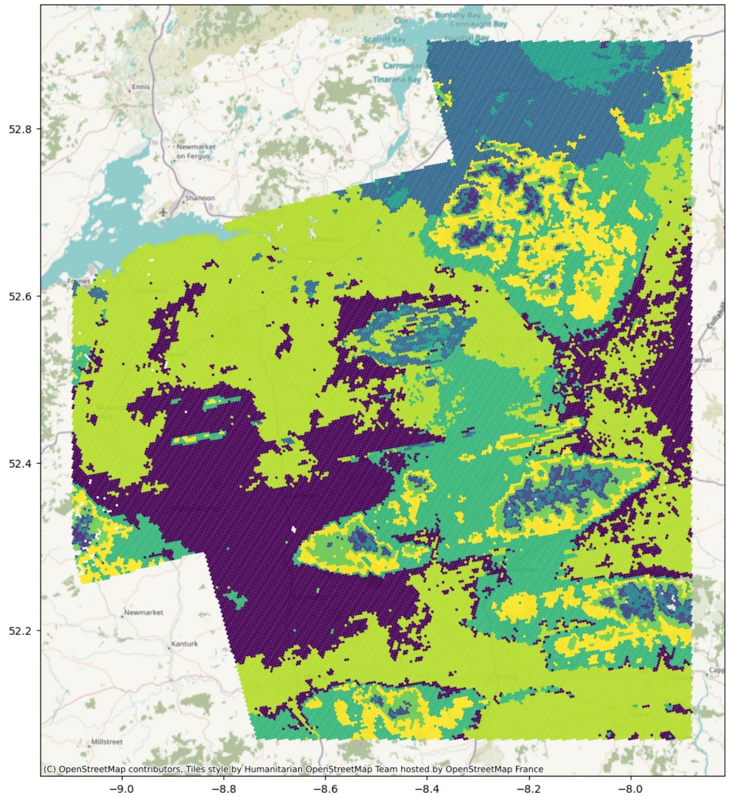


FEATURE STACK EXAMPLE

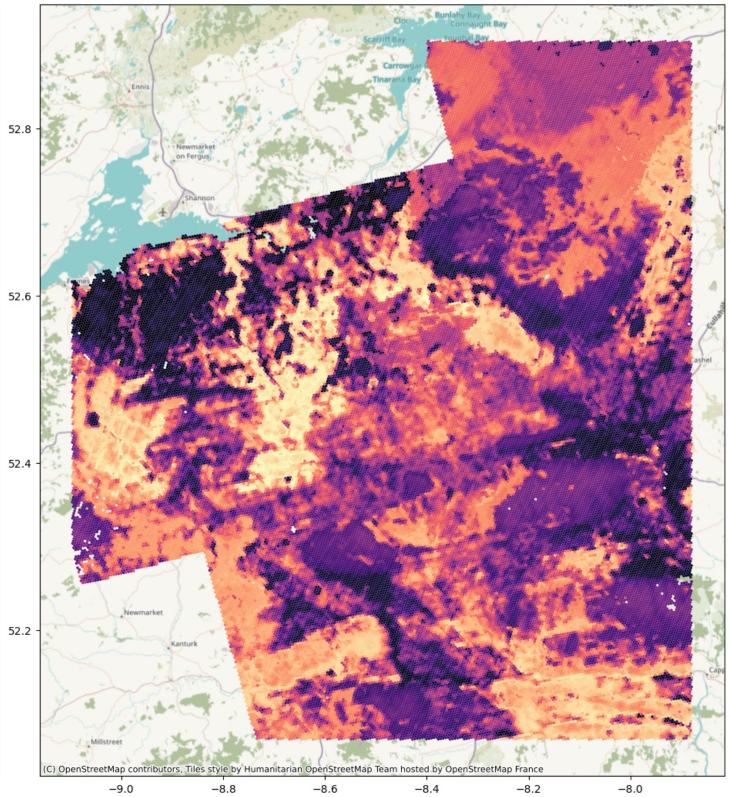


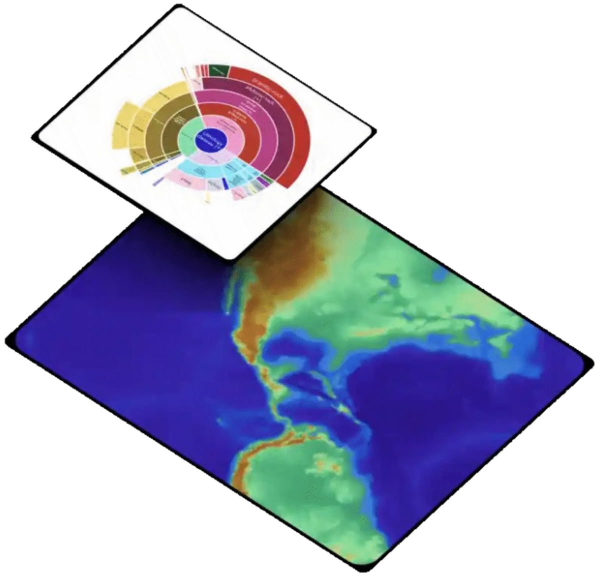
- Example from Limerick, Ireland, intrusion through limestone
- Features stack includes:
  - Magnetics, satellite data and radiometrics and geological map.
- Perform kMeans clustering or PCA and t-SNE ML methods
- Explore the result spatially on the map!

K-Means



T-SNE 2





Scandinavian Highlands
HexResponder

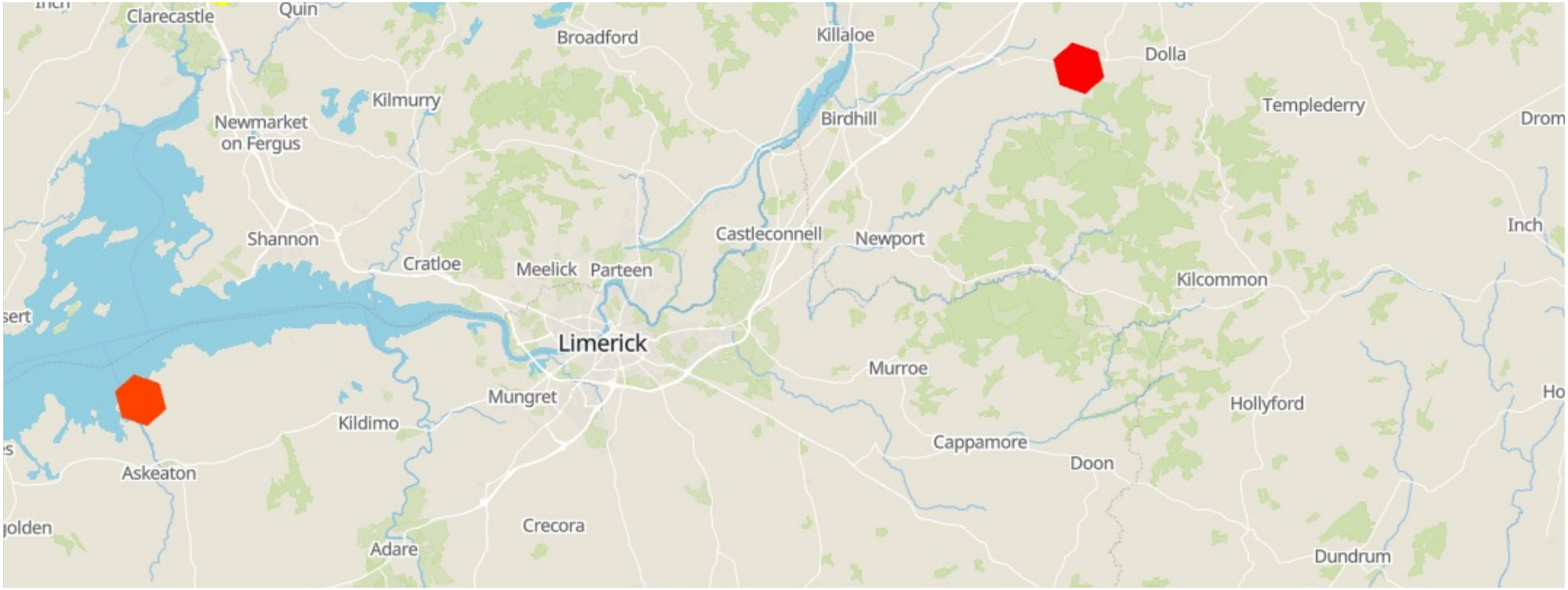
THANK YOU FOR YOUR ATTENTION!

QUESTIONS?

PLEASE REACH OUT HERE:

WWW.SCANDINAVIAN-HIGHLANDS.COM

OR ON OUR SOCIALS:



PICO EXTRA SLIDES

Traun, Sandø & Jensen,
Scandinavian Highlands

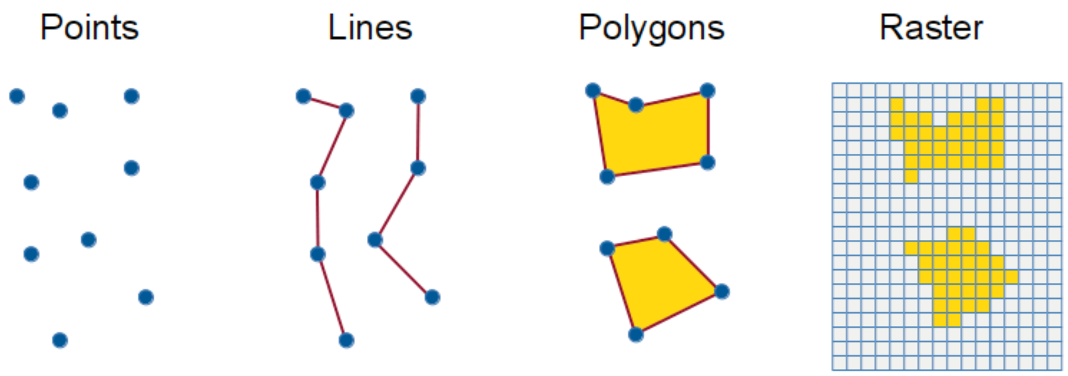
SPATIAL DATA GEOMETRIES

Vector data

- Coordinates giving points (e.g. samples), lines (e.g. faults), and polygons (e.g. geological maps)
- Typically ESRI/GIS shapefiles
- Other common formats: GeoJSON and Geopaquet

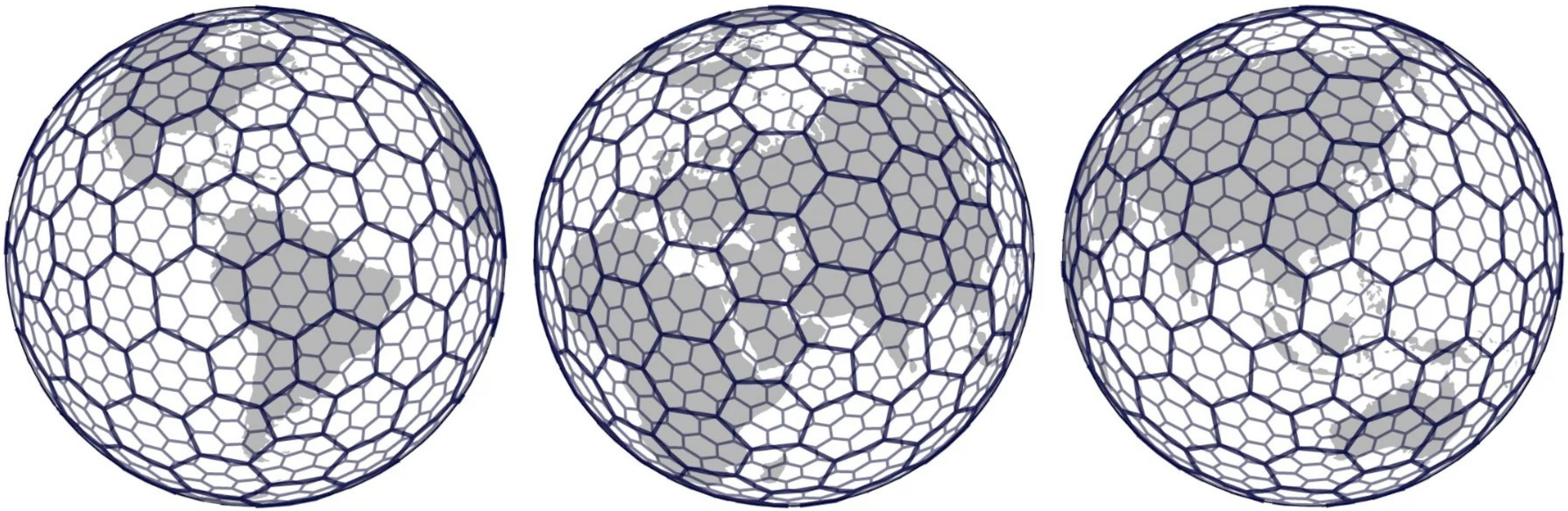
Raster data

- Data in an even grid of x,y coordinates in local projection, usually represented by a corner coordinate and grid spacing.
- Pixel map with a measured value, e.g. elevation or magnetics anomaly for each pixel
- Common formats: GeoTIFF, GRD, GXF, HDF5



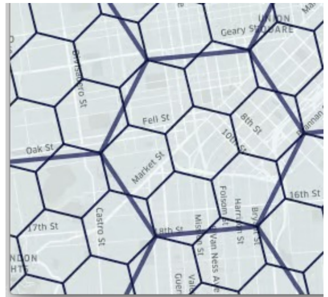
WHAT IF YOU COULD USE THE GEOGRAPHICAL POSITION TO SIMPLY JOIN SPATIAL DATASETS AND ANALYSE/PREDICT ACROSS SPATIAL GEOLOGICAL/GEOGRAPHICAL DATASETS?

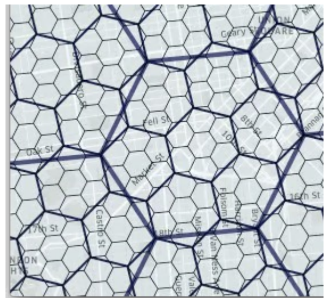
THAT IS OUR MAIN MISSION AT SCANDINAVIAN HIGHLANDS!

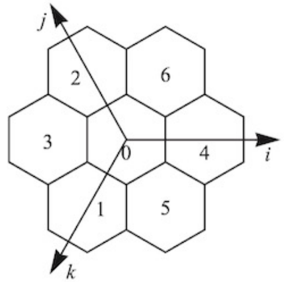


HEXAGONS AND UBER H3

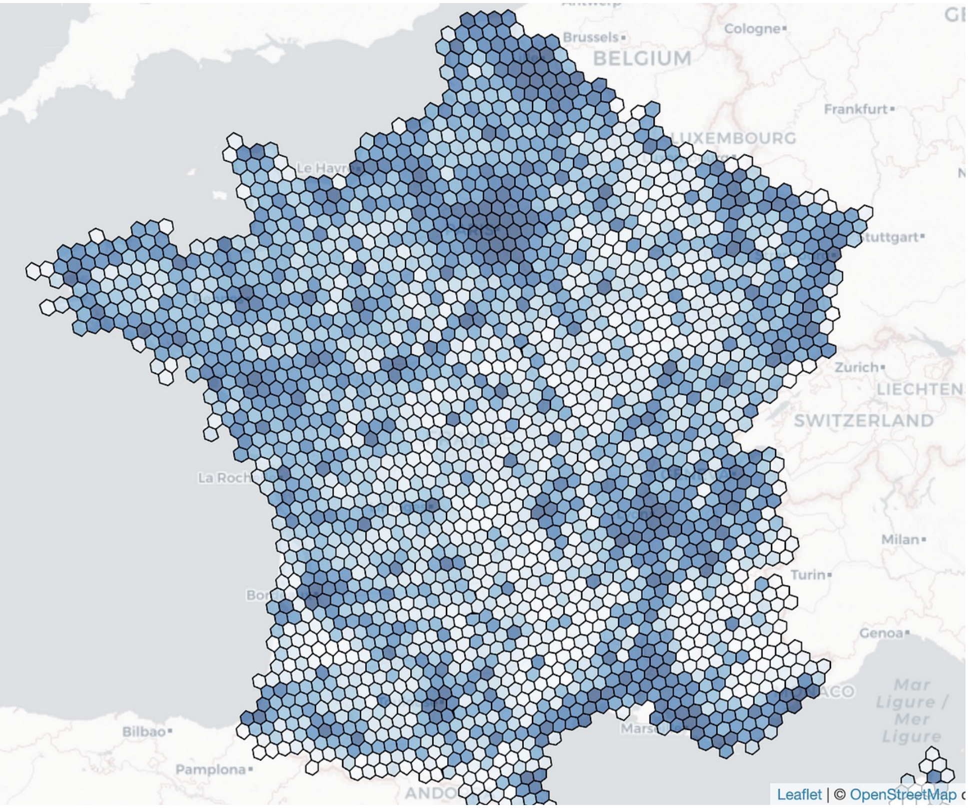
1. Developed by Uber for analysing pick-ups/drop-offs in cities and calculate routes and traffic flow. Open source since 2018.
2. Global discrete grid system
3. Earth's surface covered by hexagons at different resolutions (0 to 15), down to ~1m^2 area for the smallest hexagon.
4. Resolutions connected in a hierachy of parent cells (coarse) and children cells (fine)
5. Each hexagon cell has a "name", which is a translated binary code that describes:
   1. Its position and resolution
   2. Its relation(s) to parent, children and neighbours
   3. Example: 85283473fffff







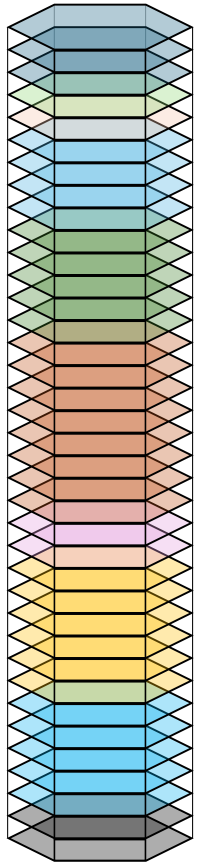
HEXAGONIZE SPATIAL DATA



1. Point becomes hexagon cell
2. Lines become a path of cells
3. Polygons are filled by cells
4. For raster, each pixel becomes a cell on the best fitting resolution
5. Hexagon cells inherit the values of the source
6. Finding fitting resolutions important!
7. Data on hexagons can be aggregated for coarser resolutions, similar to histograms or hexbins

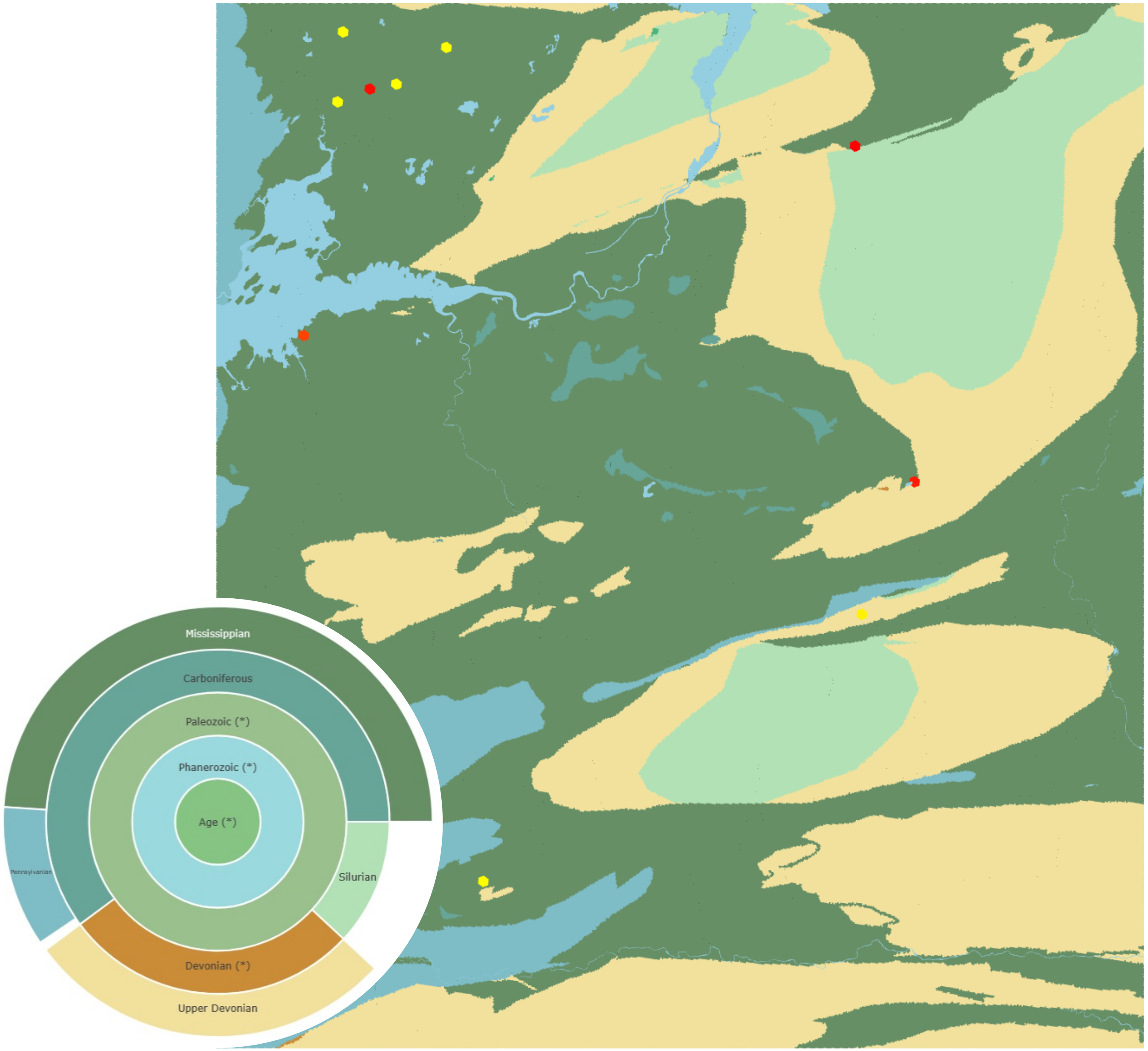
JOIN DATA USING HEXAGONS – FEATURE STACKS

1. Visualisation, descriptive statistics and analyse across geological data types (e.g. for mineral exploration)
2. Machine learning: Predictions, modelling, clustering which requires a "Feature" table set
3. A feature table for ML could be a stack of all data sources available in an area on the hexagons
4. We collect geological data, calibrate them to hexagons and standardize categorical variables into vocabularies.
5. We are developing an interface called HexResponder, which can visualise, analyse and predict based on these feature stacks in a no-code browser workflow

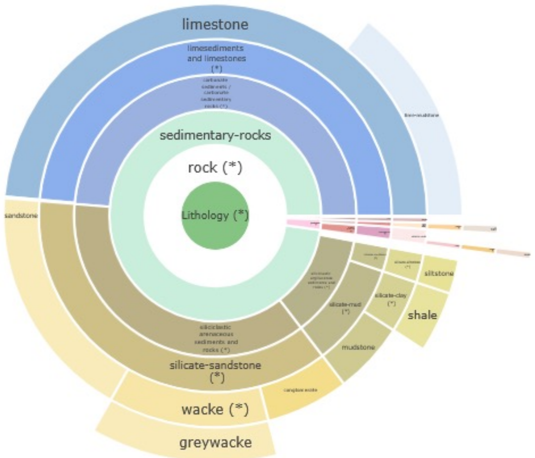


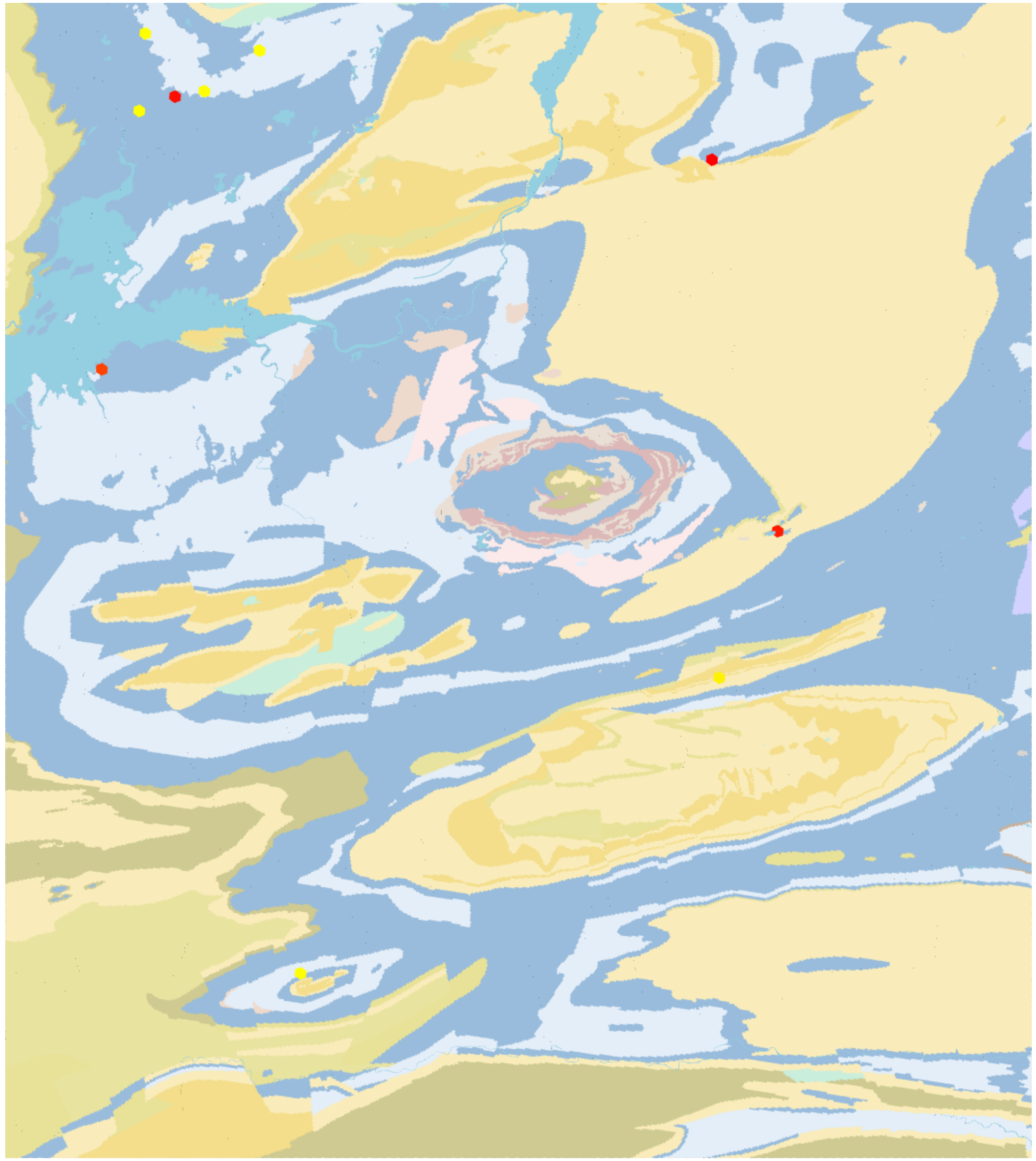
EXAMPLE: LIMERICK, IRELAND

THE LIMERICK REGION IN IRELAND CONTAINS SEVERAL REGISTERED SILVER, LEAD AND ZINC DEPOSITS, THE LOCATIONS OF WHICH ARE MARKED IN YELLOW AND RED HEXAGONS.
THE AREA CONTAINS AN IGNEOUS INTRUSION, THAT CUTS LIMESTONES AND CLASTIC SEDIMENTARY ROCKS OF CARBONIFEROUS AND DEVONIAN AGES.
THE DATA LAYERS ON THE COMING SLIDES ARE FROM THE GEOLOGICAL SURVEY IRELAND, TELLUS PROJECT.

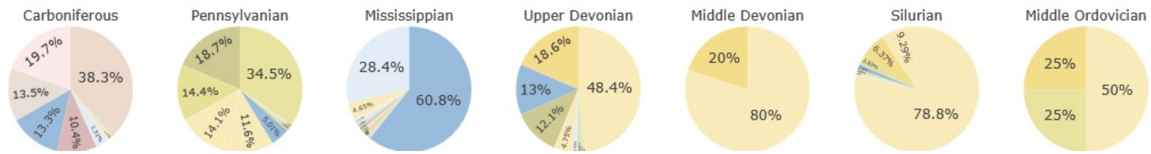


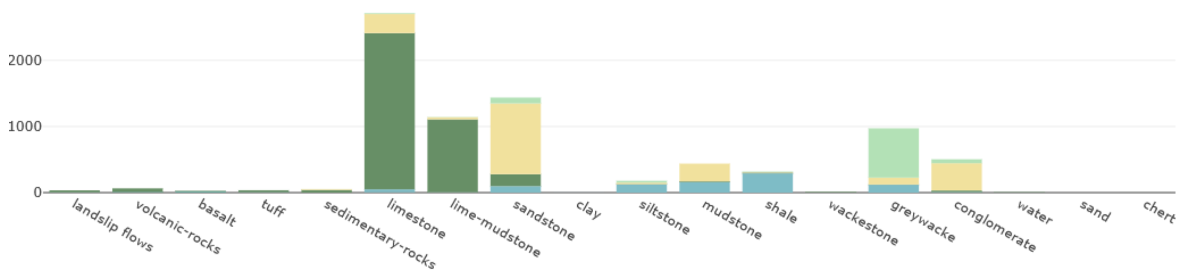
GEOLOGICAL MAP OF THE LIMERICK REGION. NOTICE HOW THE LOCATIONS OF DEPOSITS COINCIDE WITH TRANSITIONS IN ROCKTYPES.

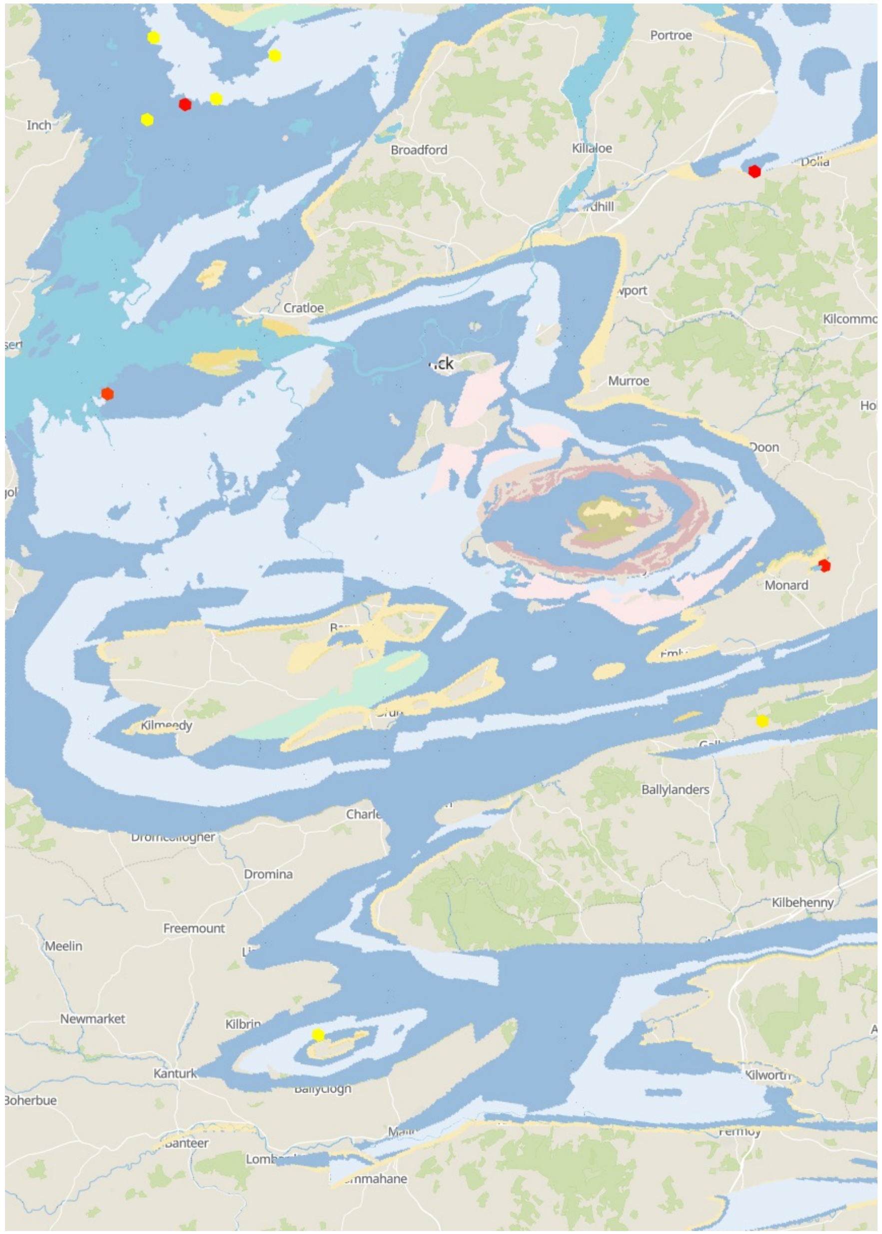




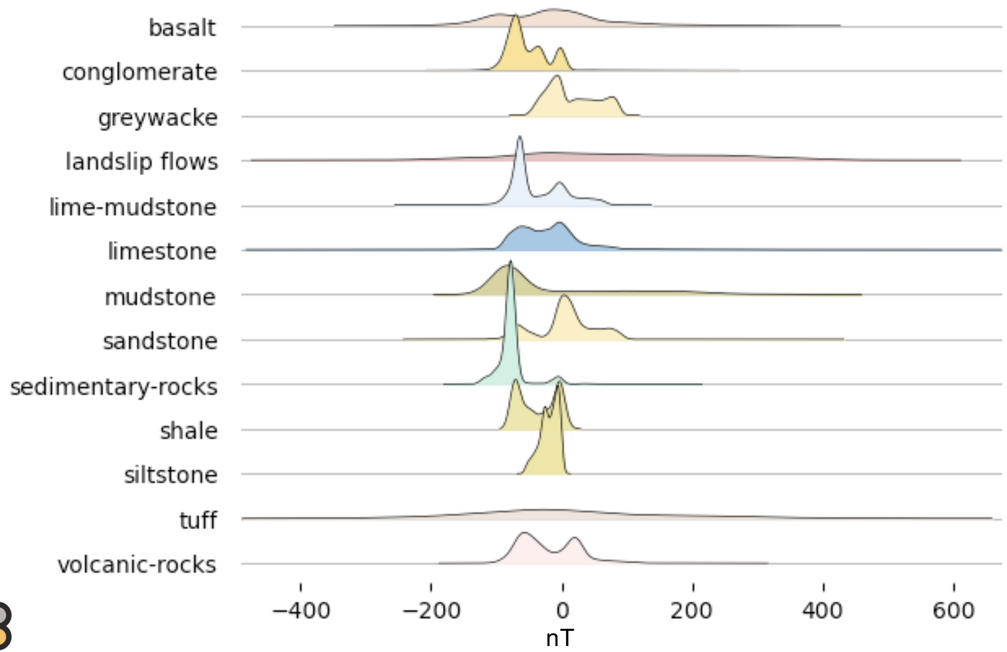
USING THE HEXAGONIZED FEATURE STACK, WE CAN EXPLORE THE CORRELATION BETWEEN ROCK TYPES AND AGES IN PIE AND BAR PLOTS.
E.G. THE MISSISSIPIAN ROCKS ARE DOMINANTLY LIMESTONE AND LIME-MUDSTONE.

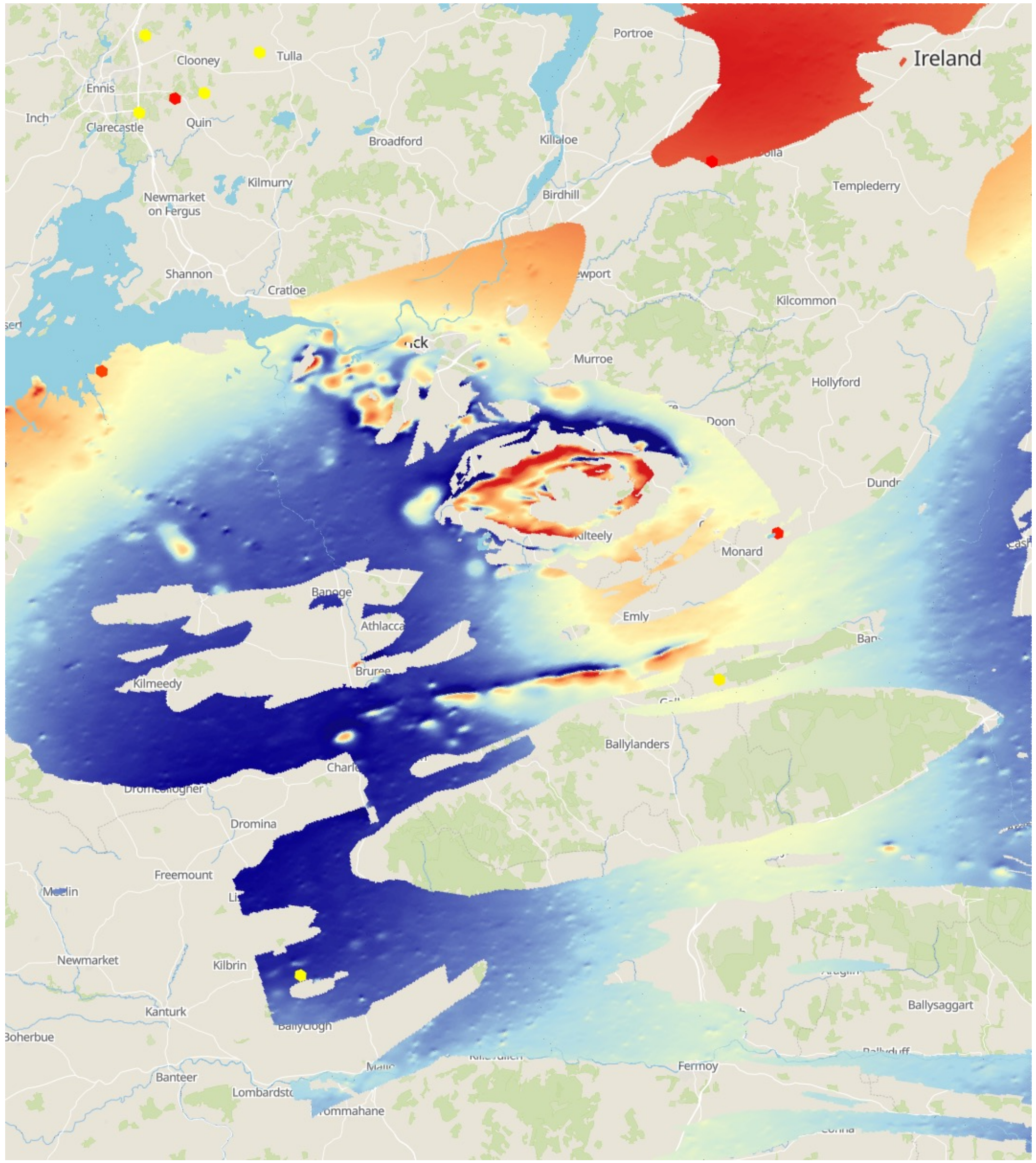






WE CAN ALSO EXPLOXE THE VARIATION OF GEOPHYSICAL FEATURES LIKE MAGNETIC ANOMALY GROUPED BY ROCK TYPES. LIMESTONE CLEARLY A BIMODAL DISTRIBUTION WITH A HIGH AND LOW MAGNETIC LIMESTONE VARIANTS. THESE CORRELATE WITH THE INTRUSION AND KNOWN FAULTS LINES.





WE CAN CREATE A LIMERICK FEATURE STACK BASED ON GEOLOGICAL MAPS, GEOPHYSICAL SURVEYS, AND SATELLITE DATA

These include:

Maps of rock types and ages, magnetic anomaly survey, radiometry surveys (totals, K, Th and U), satellite elevation and calculated slope data, and satellite emmisivity vegetation index.

References:

- Geological Survey Ireland. (n.d.). *Tellus: Data & Maps*. Retrieved 27 April 2025, from https://www.gsi.ie/en-ie/programmes-and-projects/tellus/Pages/Data-and-Maps.aspx
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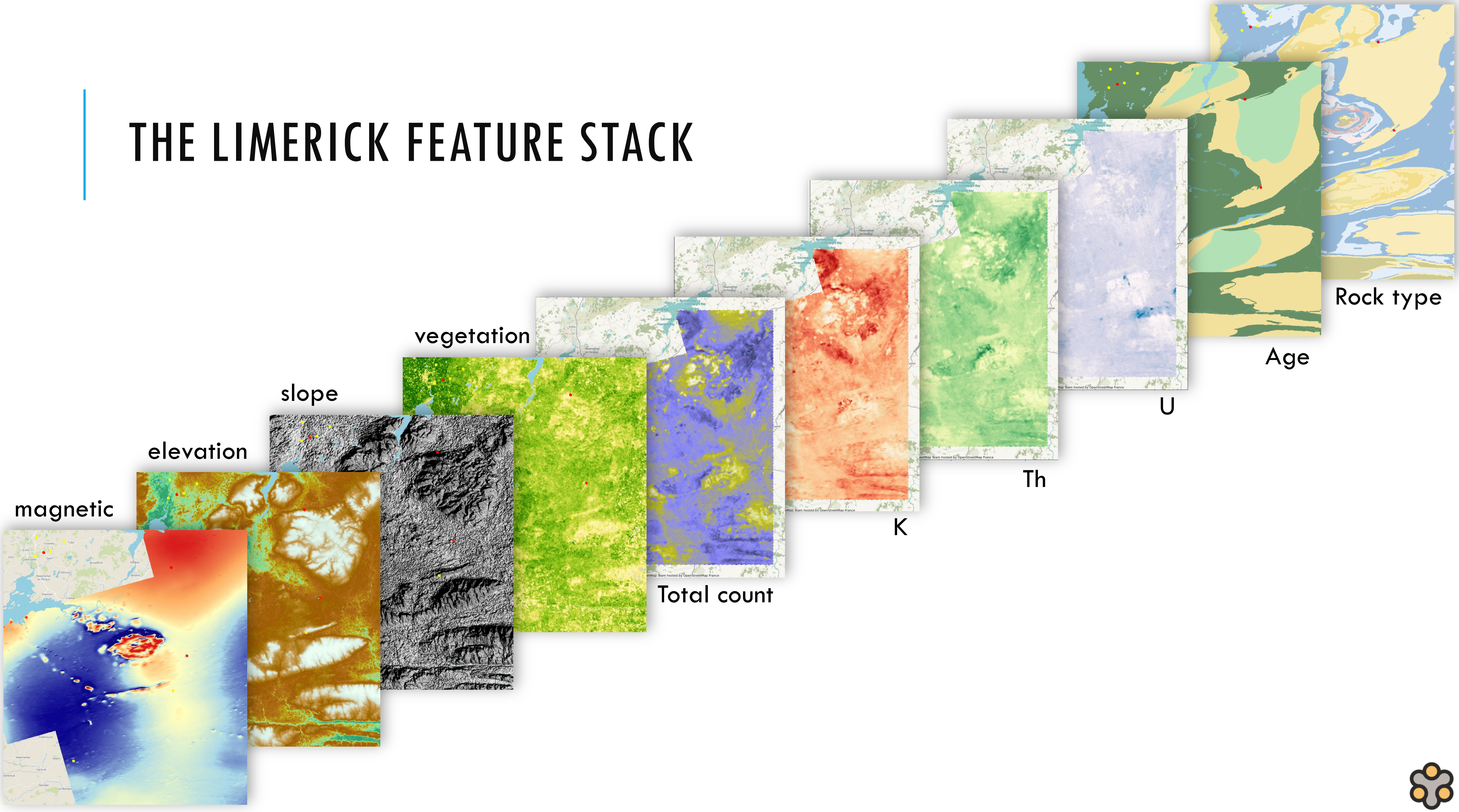
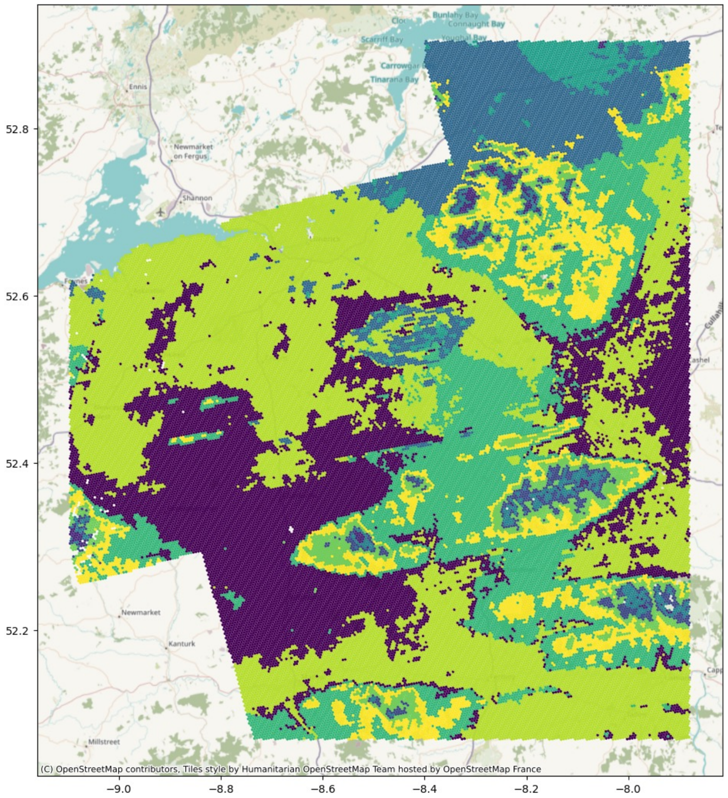
THE LIMERICK FEATURE STACK

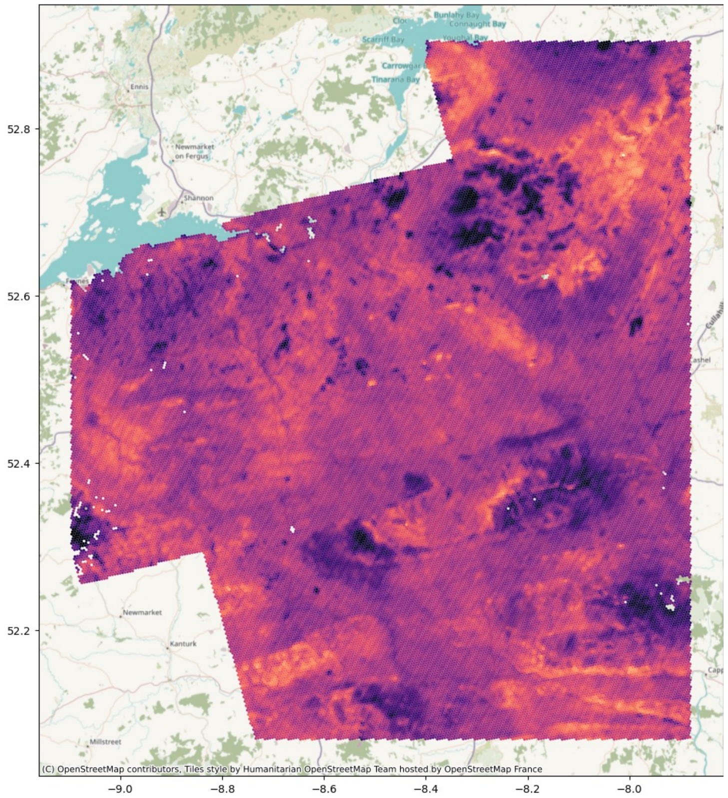


NOW, WE CAN START DOING MULTIPLE FEATURE LEARNING, E.G. K-MEANS CLUSTERS, PRINCIPAL COMPONENTS, OR T-SNE, AND SEE THE RESULTS ON THE MAP USING H3! NOTICE HOW DIFFERENT MODELS HIGHLIGHT DIFFERENT PATTERNS IN THE REGION.

K-Means



PCA 1



T-SNE 2