Neural network based predictive mapping with advangeo® and its application in the AEGOS project

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AEGOS

AFRICAN-EUROPEAN GEORESOURCES OBSERVATION SYSTEM

advangeo®

Prediction Software

GRSG AGM 2010
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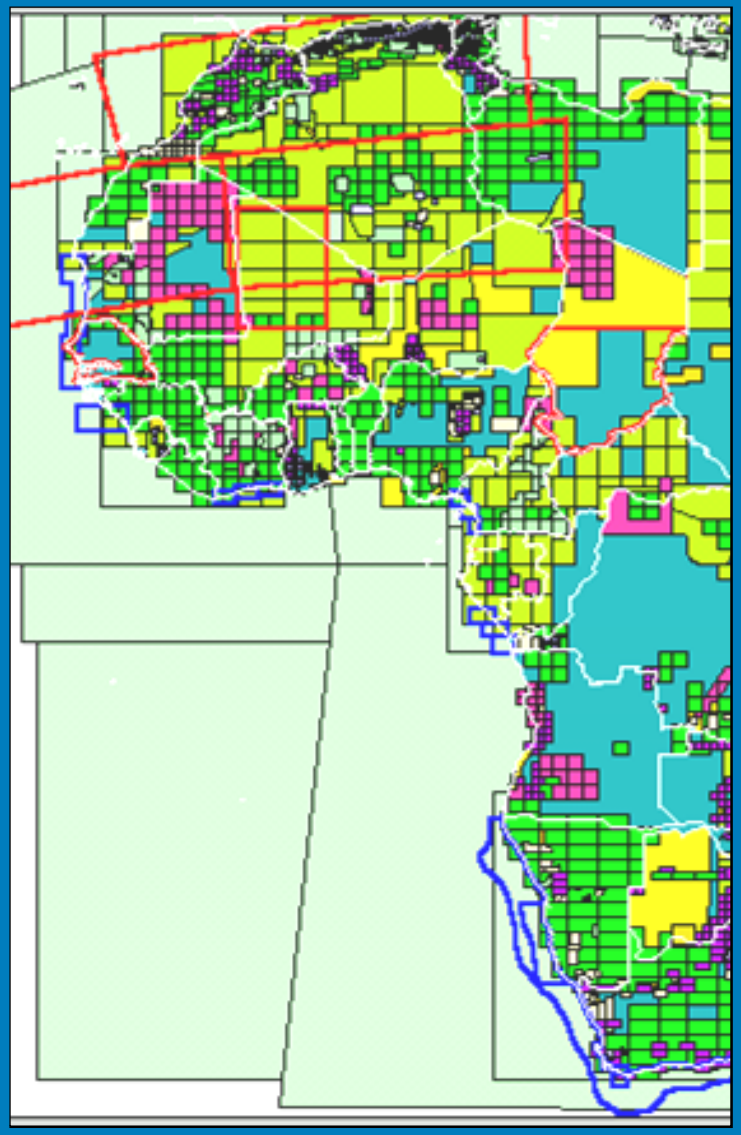
Agenda

- **AEGOS: African-European Georesources Observation System**
  - Context / Objectives
  - Project Team and Organization
  - Spatial Data Infrastructure
  - Contribution to GEO / GEOSS
- **Innovative Projects in the Frame of AEGOS: Predictive Mapping with advangeo®**
  - Theoretical Background: Artificial Intelligence / Artificial Neural Networks
  - Short Presentation of Developed Software: advangeo®
  - Description of Work Methodology:
    - Mineral Deposit / Occurrences (Au): NW-Ghana
    - Formation of Erosion Gullies: Limpopo / South Africa
  - Further Case Studies
- **Outlook / Summary**

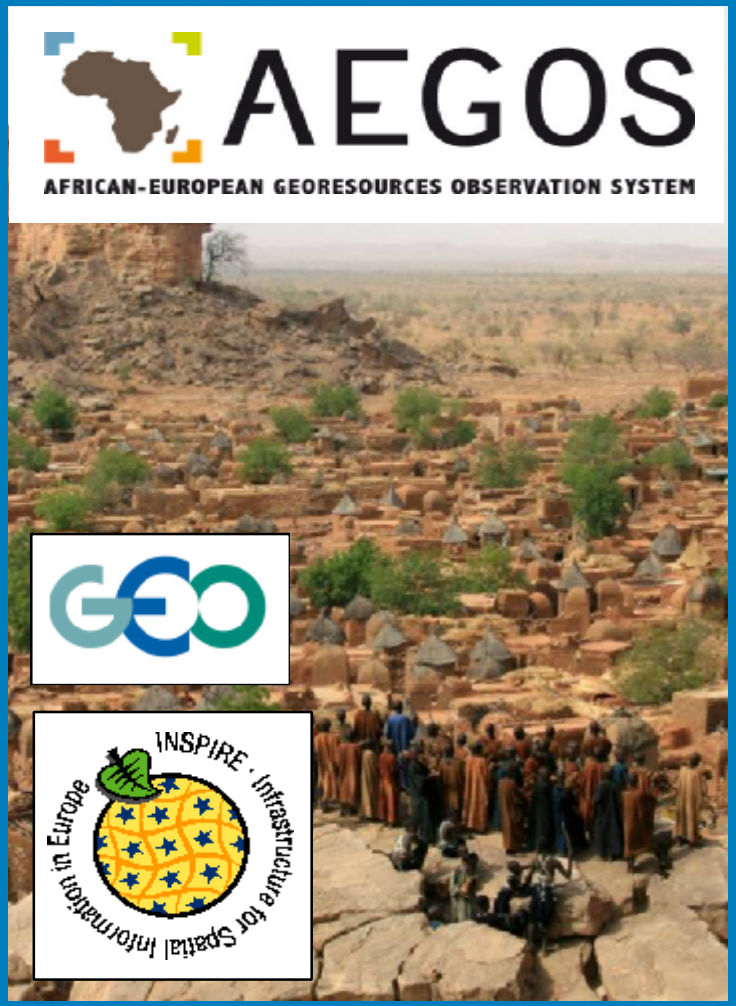
AEGOS: Context



- Africa has an important share of the global mineral resources and reserves – necessary for national and international economies: **more than 40% of the world known reserves in bauxite, manganese, cobalt, gold, diamond, platinum, rhodium**

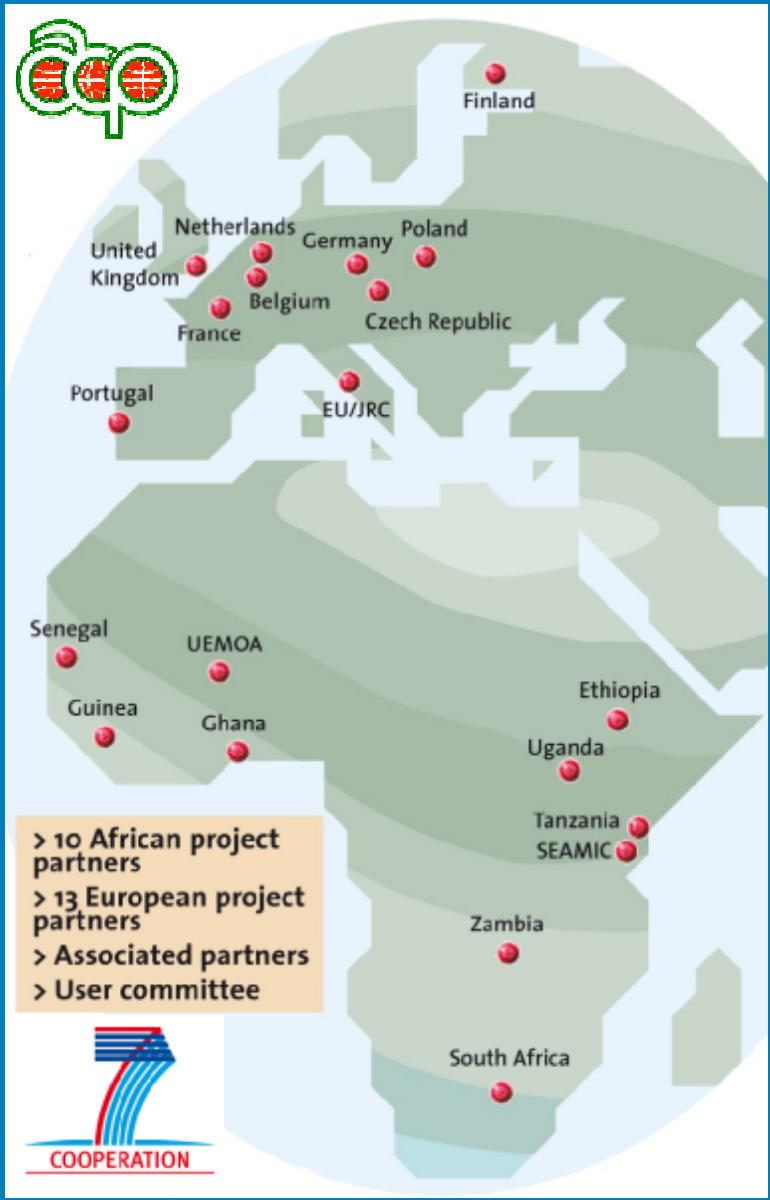
- An unique archive of Africa-related geoscientific data and information exists
  - they were acquired by African and European geoscientific organisations;
  - public, disseminated, partly hard to identify and access;
  - multiple formats, diverse geometric projections, several languages, under various custodianships;
  - they should be identifiable and accessible thanks to modern IT.

African-European Georesources Observation System



- Strengthen the sustainable use of underground resources in Africa by **designing the Spatial Data Infrastructure (SDI) for Georesources** based on interoperable geoscience data and user-oriented services
- **Safeguard, share and valorize** the knowledge and data archived in African and European geological surveys
- **Support geoscientific communities** and **institutional decision-makers** for sustainable development public policies
- **Elaborate common strategies** for capacity building and training programmes

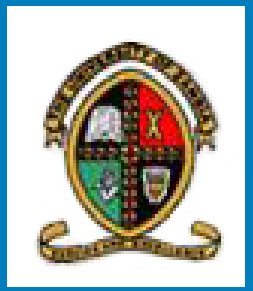
AEGOS: ACP – EU Initiative in FP7-RTD



- **Preparatory phase** (2008-2011) to design a multi-national georesources observation system
- **Main targets**: institutional decision-makers, investors, geoscientific communities and education
- **9 European** geological surveys
- **8 African** counterparts: geological surveys, ministries of mines, school of mines
- **4 International** organizations: EU Commission (Joint Research Centre), CIFEG, UEMOA, SEAMIC

AEGOS: Project Team

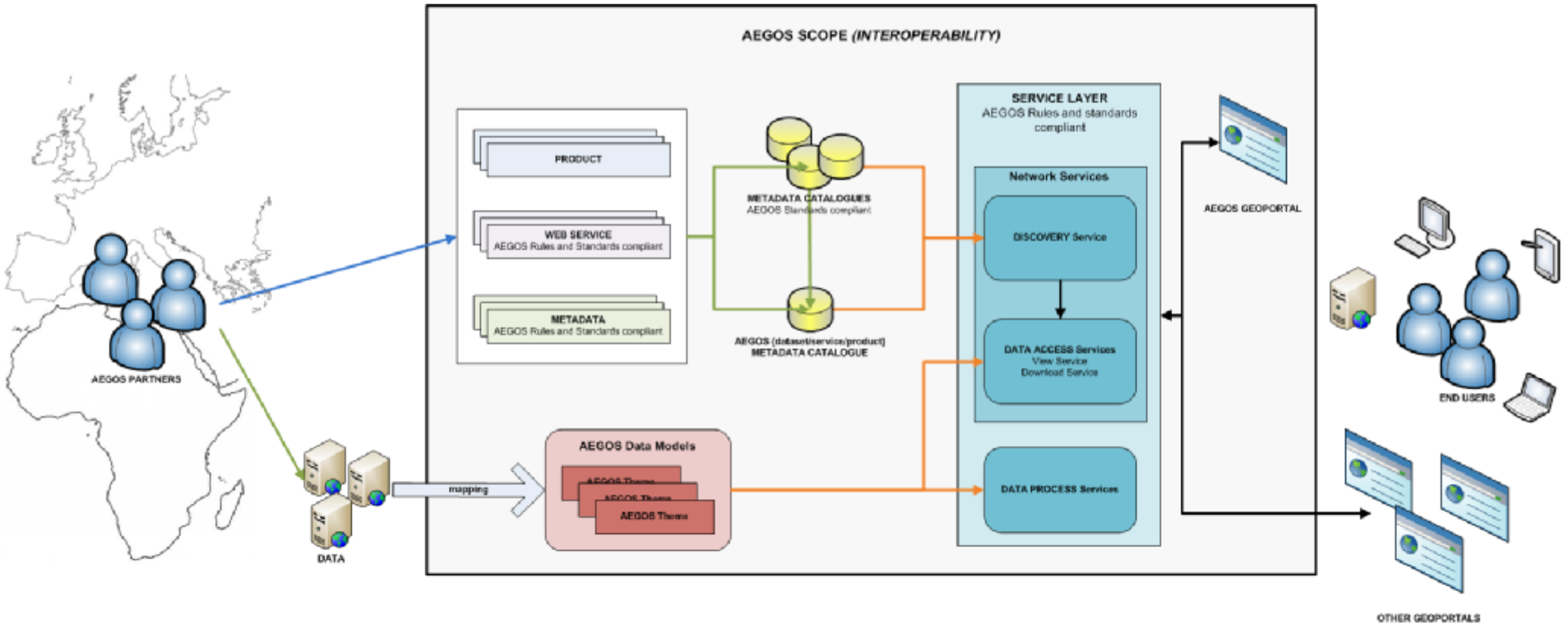
Consortium of 23 partners



AEGOS: Associated Partners (Subcontractors)

- Geological Survey of Tanzania
- Direcção Nacional de Geologia, Mozambique
- Geological Survey of Sweden
- Cranfield University, United Kingdom
- Royal Museum for Central Africa, Belgium
- EUMETSAT, European Union

AEGOS: SDI - Distributed Infrastructure



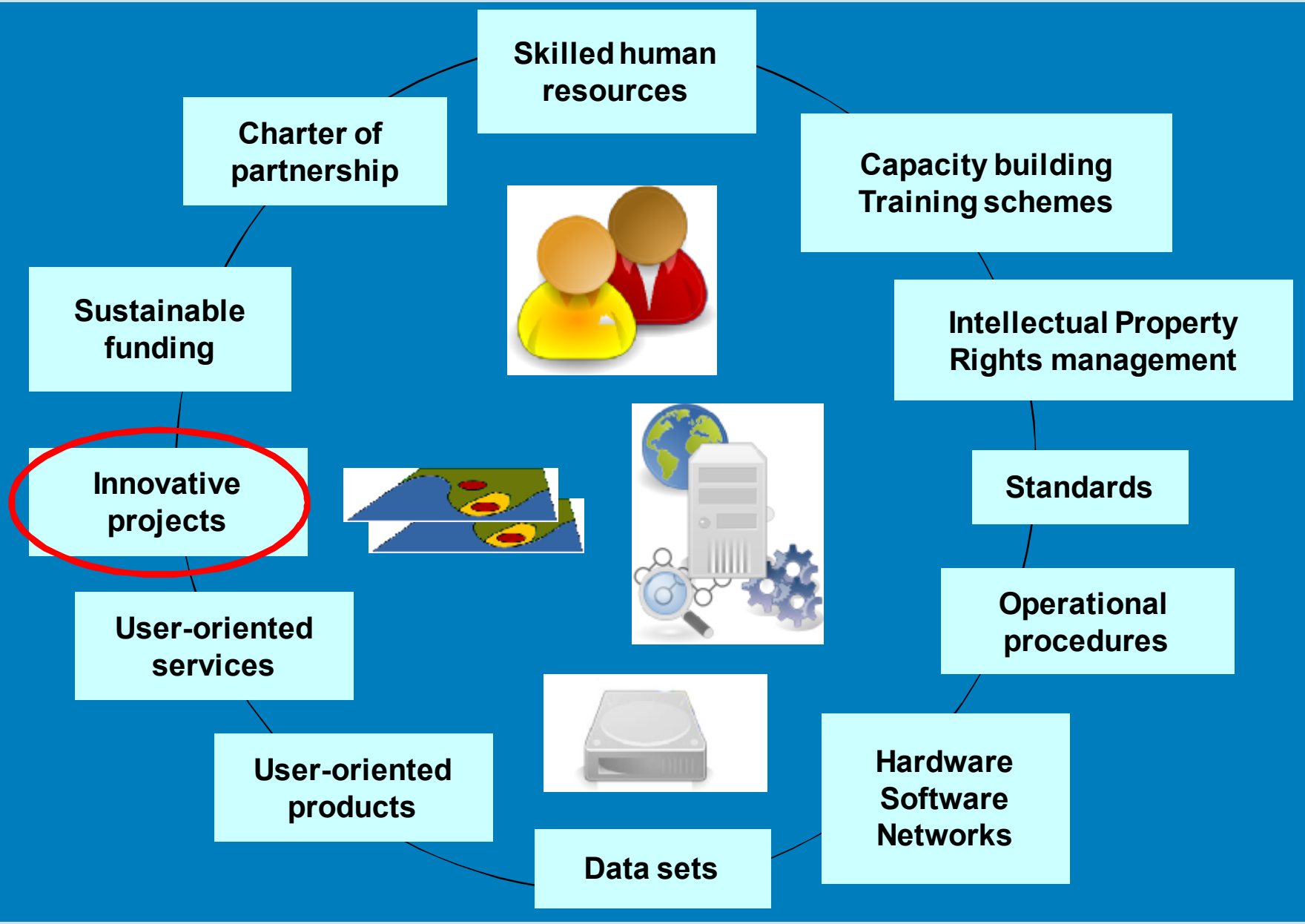
Metadata on-line
Data (on-line and off-line / e-AEGOS)
Products (on-line and off-line)
Services (customised)
Capacity building

AEGOS: Contribution to GEO and GEOSS

- AEGOS in **GEO European Research Projects** Group (DG Research)
- AEGOS in **GEO Work Plan** 2009-2011:
  Task CB-09-05d in Capacity Building Committee
  Representation in Science & Technology Committee

- **AEGOS metadata and services will be registered** into the GEOSS catalogue:
  Visibility and interdisciplinarity with georesources on Africa

AEGOS: Infrastructure Components



Innovative Projects from AEGOS

Case Study 1: *Exploration Targeting / Predictive Mapping for Au-Deposits / Occurrences in NW-Ghana*

Case Study 2: *Erosion Gullies in Limpopo, South Africa*

Predictive maps can provide a serious input into the national development strategy

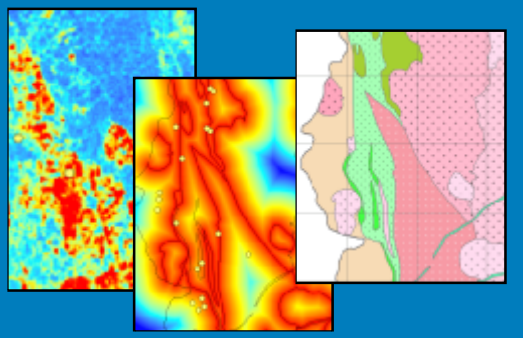
Where are Au-Deposits located ?

Modelling by:
Solomon Anum

Working Steps for Data Analysis

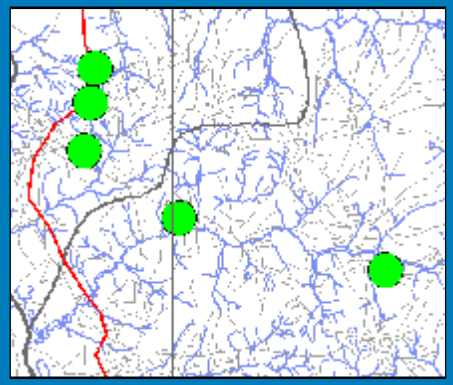
Input Data:

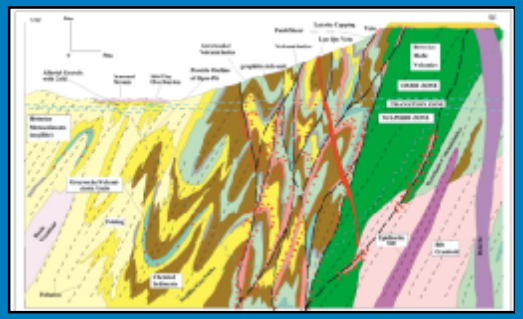
Geological Map, Tectonic Elements, Airborne Geophysical Survey



Knowledge:

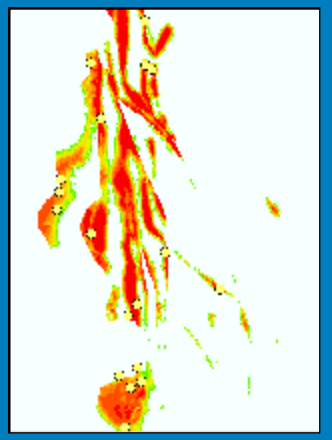
Known Deposits, Relationships





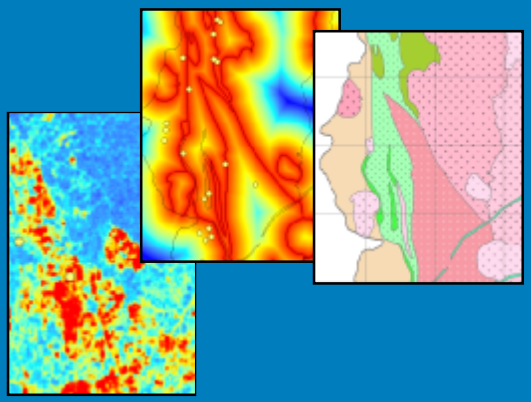
Possibilities of Data Analysis:

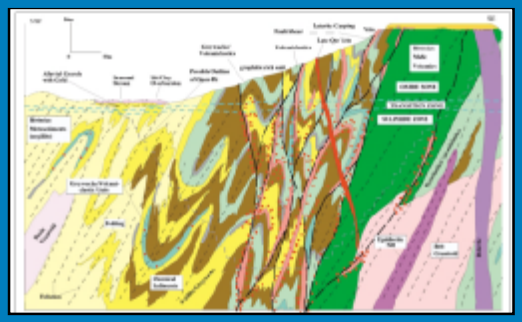
Analytical or Empirical / Statistical Approaches

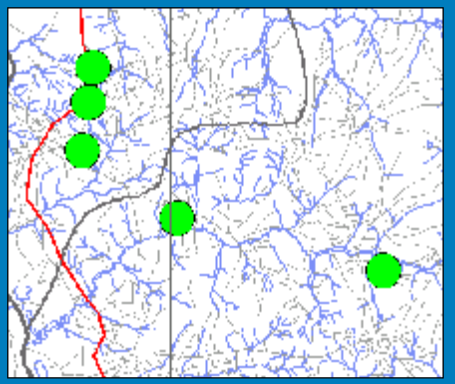


Application of Training→ Prediction Maps

Traditional Approach

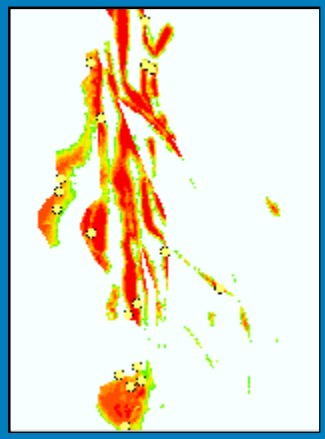




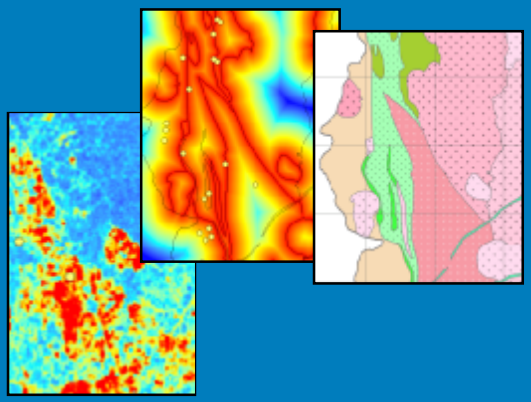


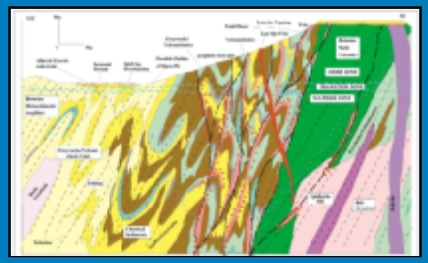
Traditional prediction methods are based mainly on the expert´s knowledge / experience supported by modern information technology

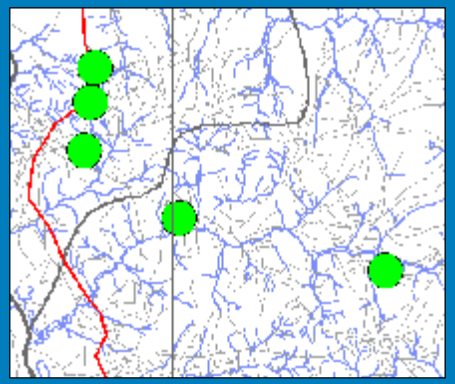
Data Analysis and Interpretation

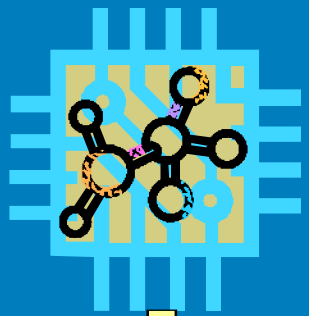


Modern Approach Using Artificial Intelligence







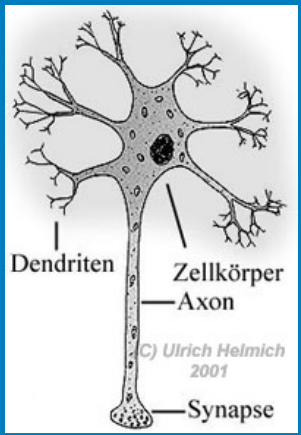


Pre-Processing

Validation

The artificial neuronal network "replaces" the experts empirical data analysis

Definition: Artificial Neural Networks

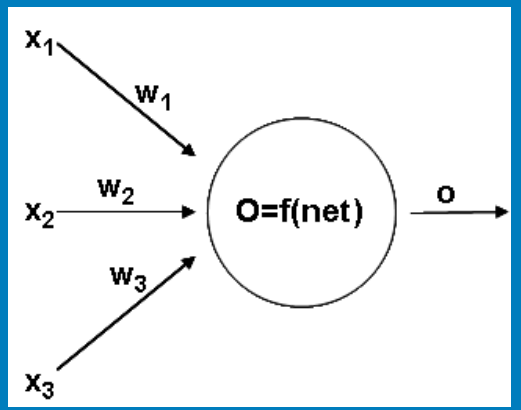


Model: Neuron Cell

- Functionality as a biological neural system
- Consists of artificial neuron cells
- Simulation of biological processes of neurons by use of suitable mathematical operations
- In most cases layer-like configuration of the neurons

The Neuron Cell as a Processor

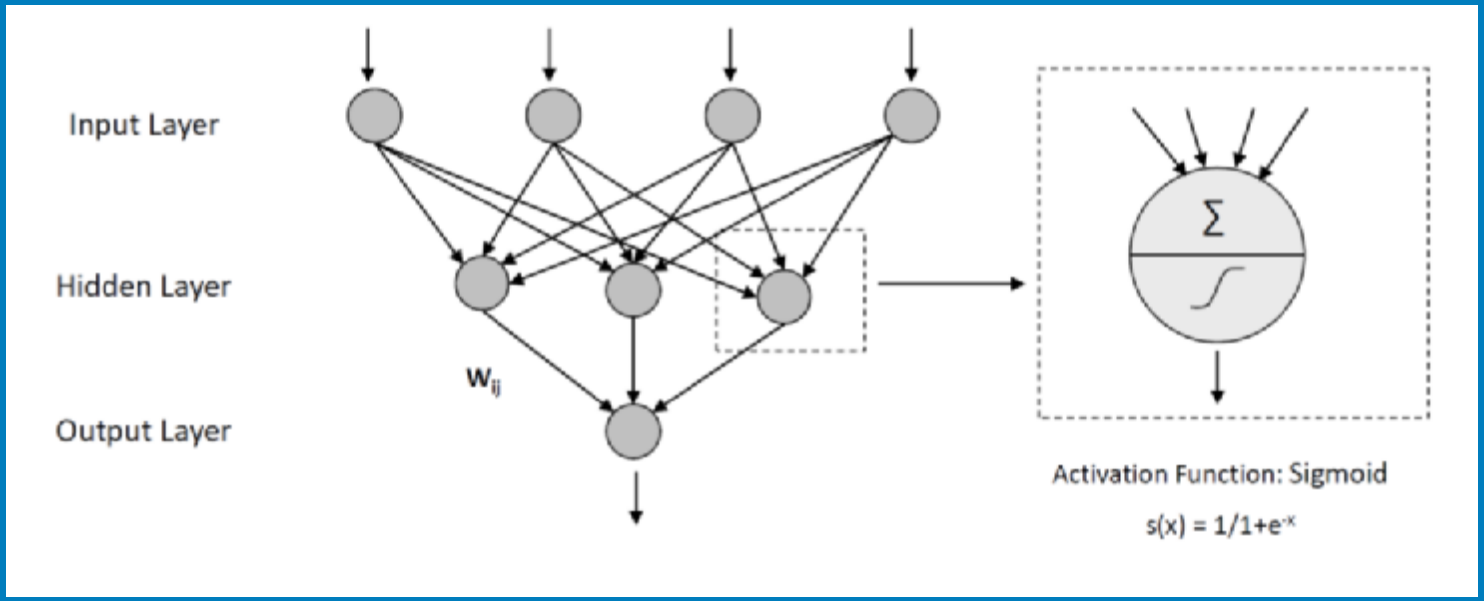
- **Connection between the neurons by weights w**
  - Enforce or reduce the level of the input information
  - Are directed, can be trained
- **Input signals**
  - Re-computed to a single input information: the propagation function
- **Output signals**
  - Activation function computes the output status of a neuron (often used: Sigmoid function)



Principle Setup of Artificial Neural Networks

Network Topology: MLP (Multi Layer Perceptron)

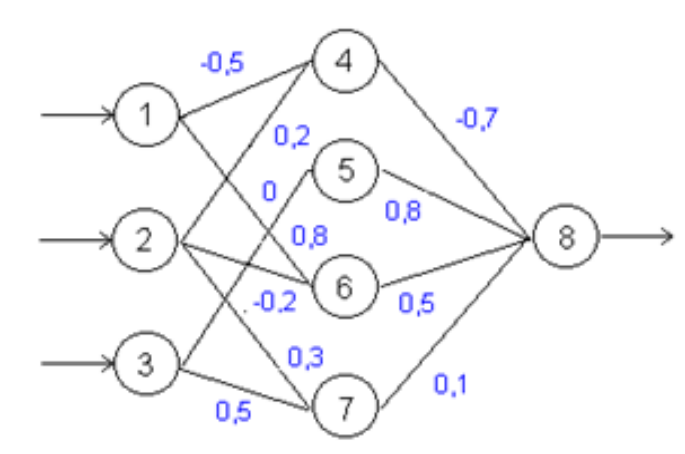
- Set-up of neurons in layers
- Direction and degree of connections
- Amount of hidden layers and neurons

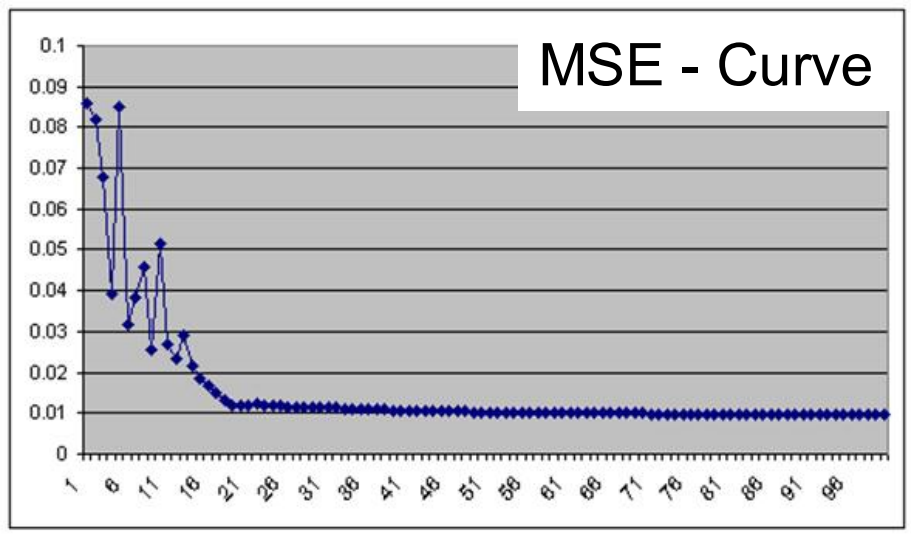


Training of Artificial Neural Networks

Learning Algorithm: Back-Propagation

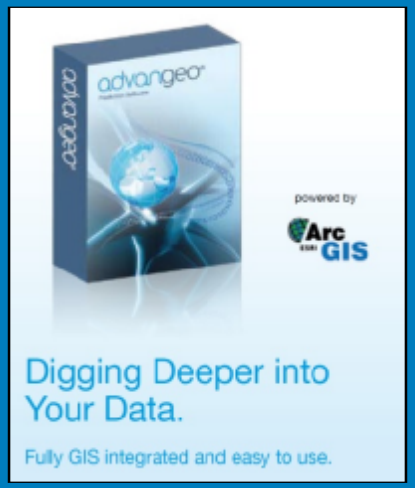
- Repeated input of training data
- Modification of weights w
- Reduces error between expected and actual output of the network





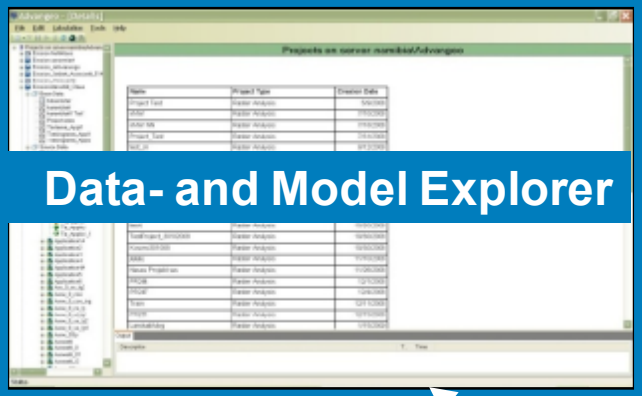
Software: advangeo

- Easy Access to Methods of Artificial Intelligence for Spatial Prediction
- Documentation of Working Steps
- Capture and Management of Metadata for Geodata
- Tools for Data Pre-Processing, Post-Processing and Cartographic Presentation
- Integration into Standard ESRI ArcGIS-Software

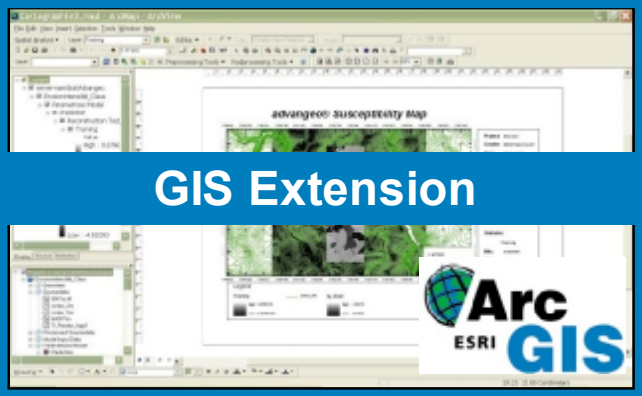


advangeo®
Prediction Software

advangeo: Software Components

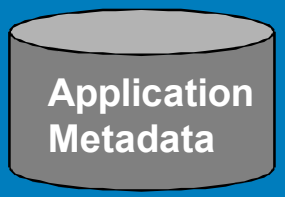


Data- and Model Explorer

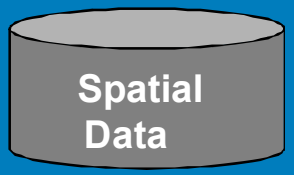


GIS Extension

Referenced
Data Sources



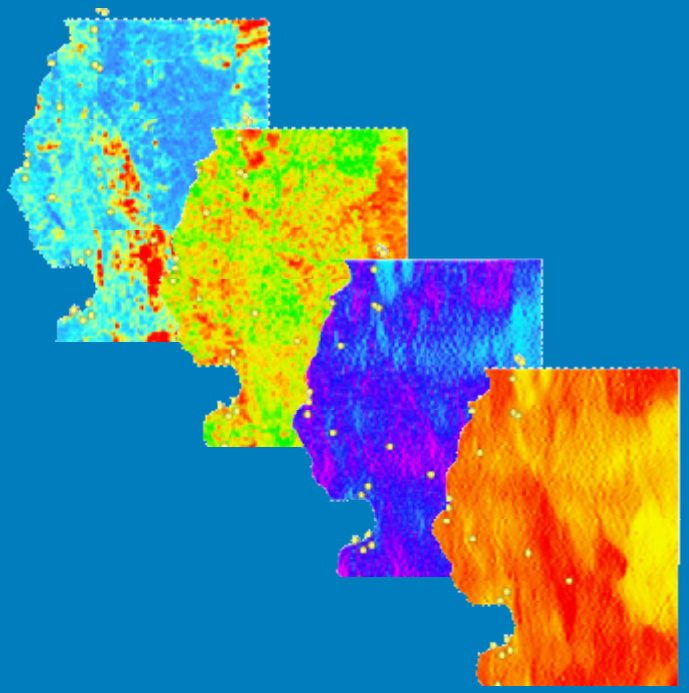
Application
Metadata



Spatial
Data

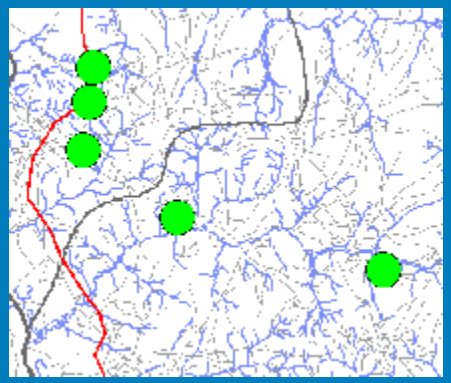
Case Study 1: Mineral Deposits (Ghana)

Input Data:
Airborne Geophysics: U, Th, K, Total, Magnetics
Distance to Tectonic Structures
Intersections of Tectonic Structures
Rock Type from Geology
Important Rock Contacts



advangeo®
Prediction Software

Trainings Data:
Known
Mineralisations

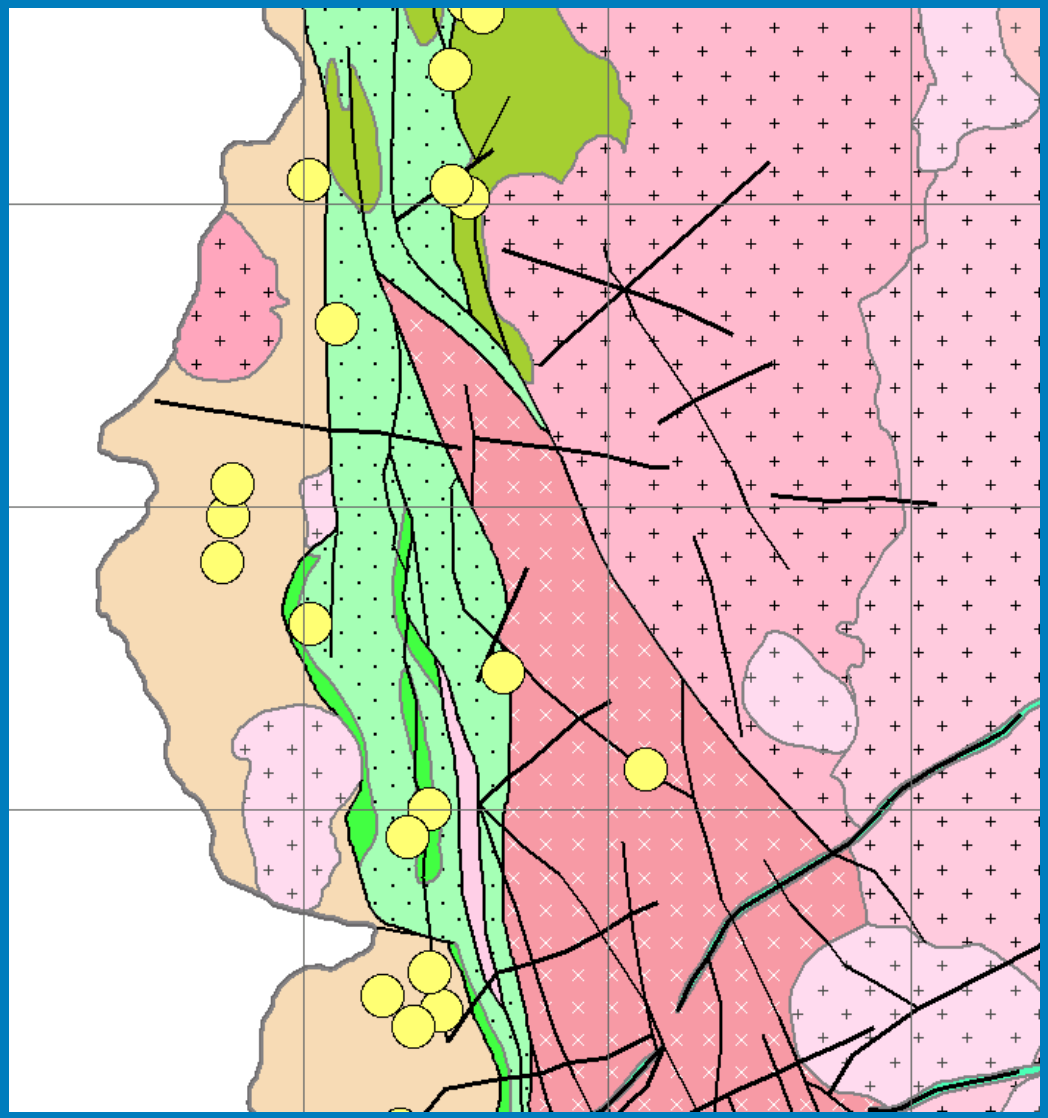


Case Study 1: Mineral Deposits (Ghana)

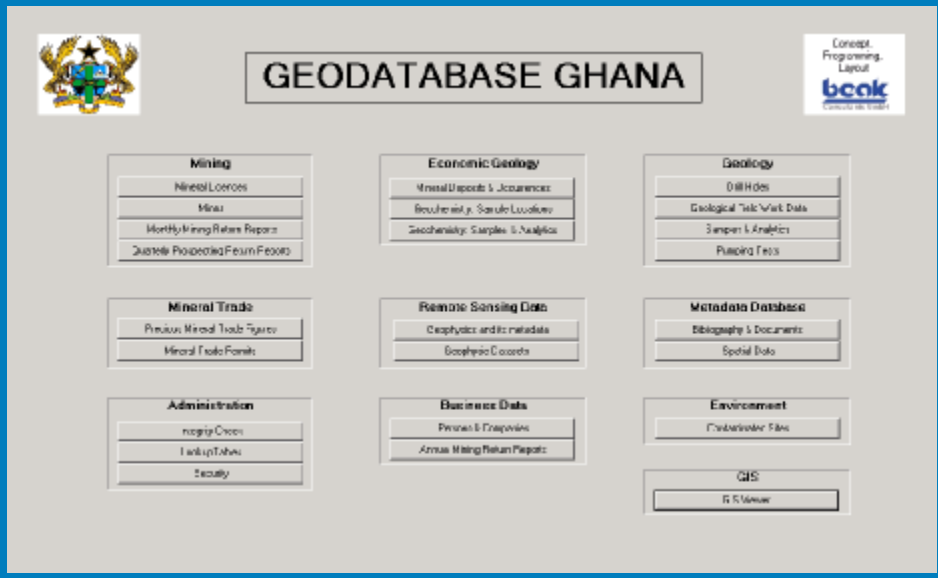
Available Data and Knowledge

- **Airborne geophysics**:
  - whole country covered, but different resolution / methodology
- **Geological maps**:
  - 1:1,000,000 (BGR-GSD Ghana, 2010)
  - 1:1,000,000 (Minerals Commission of Ghana, 2002)
  - Other scales
- **Geochemical data**:
  - selected maps only, no systematic data in a suitable density
- **Metallogenetic models** of Au ore bodies

Case Study 1: Mineral Deposits (Ghana)

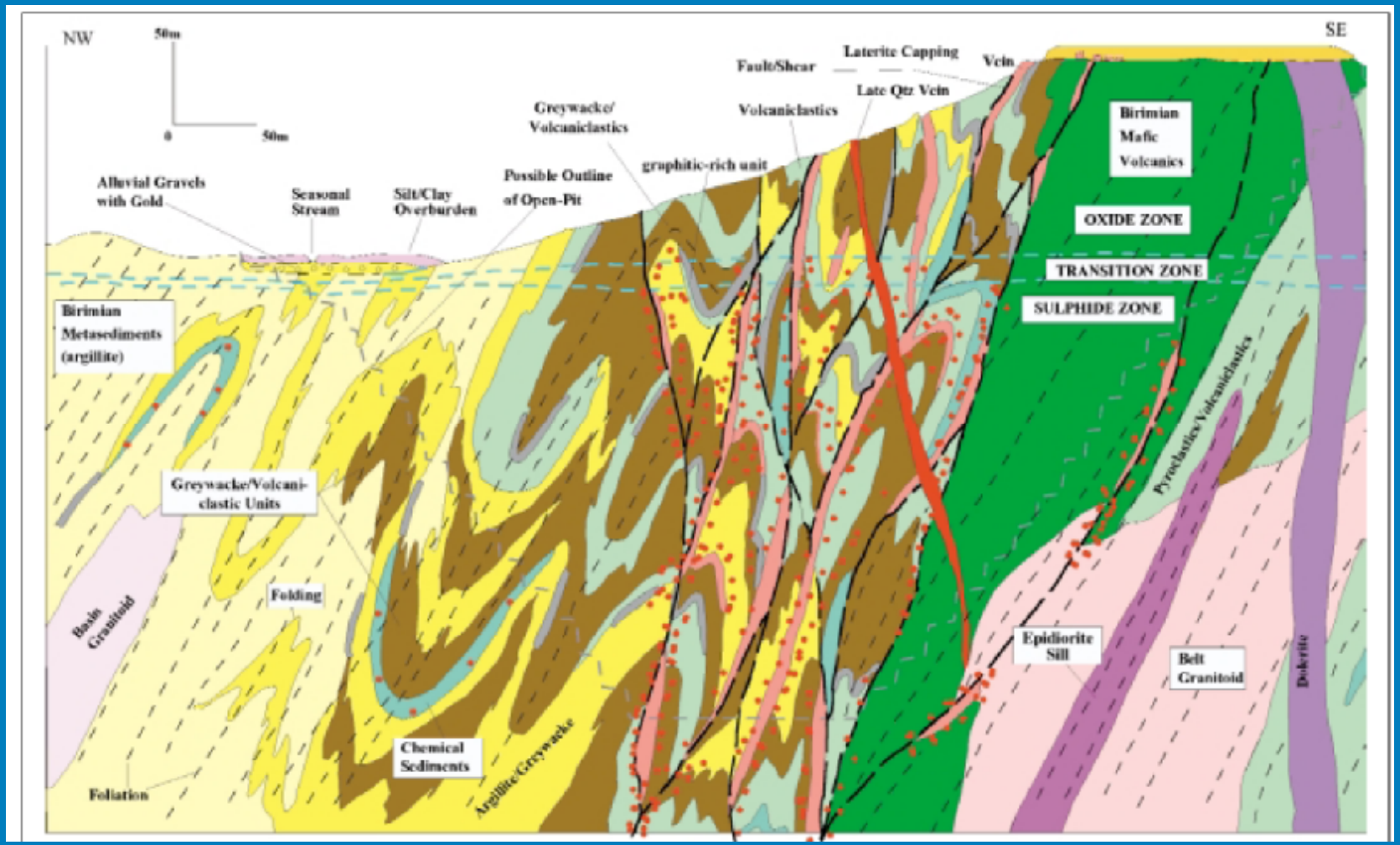


Training Data:
Known Deposits and Occurrence
From Geodatabase Ghana



Case Study 1: Mineral Deposits (Ghana)

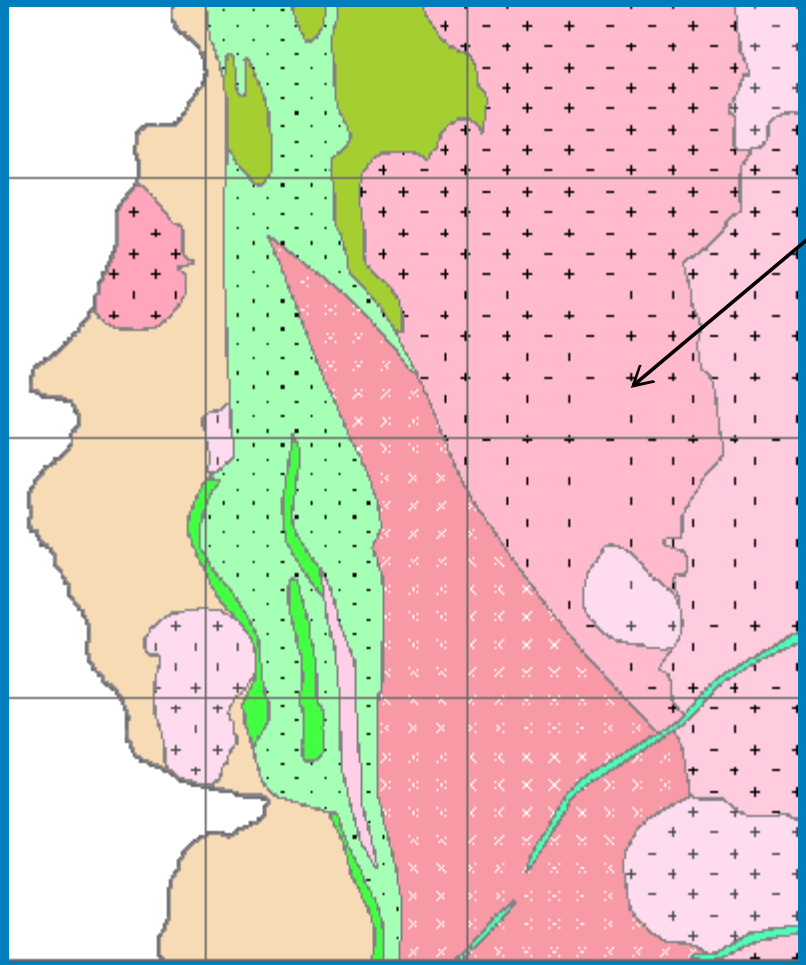
Knowledge: Existing Deposit Model

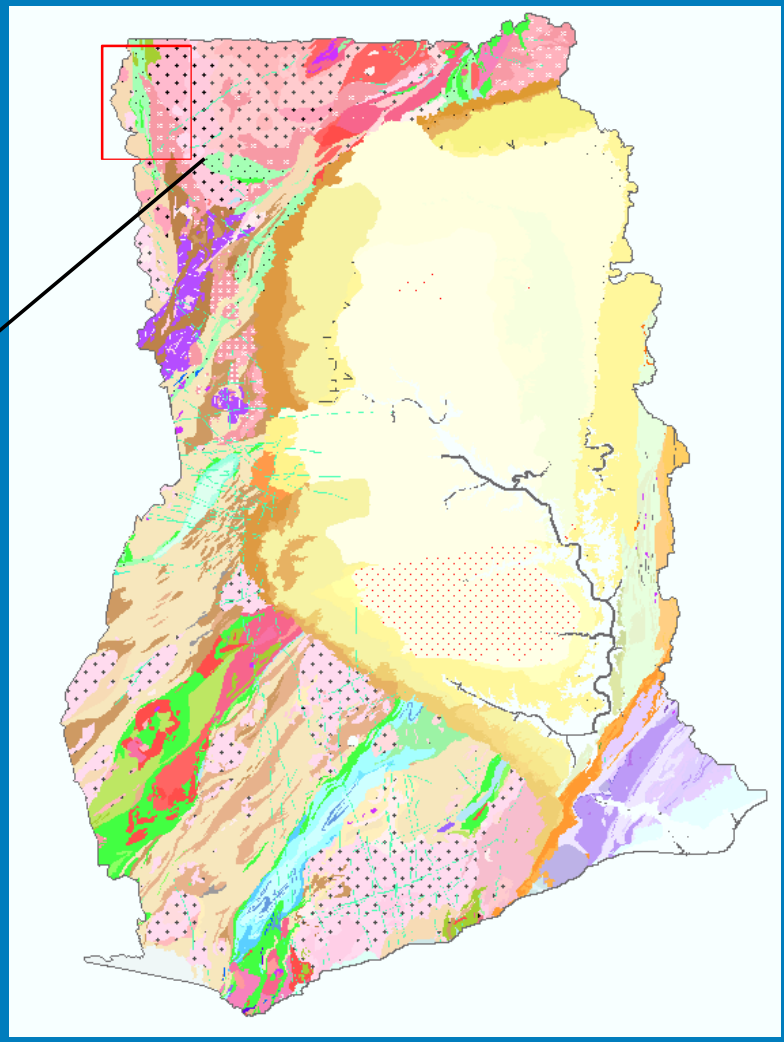


Source: Gold deposits of Ghana, Minerals Commission, Ghana, ROBERT J. GRIFFIS, KWASI BARNING, FRANCIS L. AGEZO, FRED K. AKOSAH, 2002

Case Study 1: Mineral Deposits (Ghana)

Input Data:
Geological Map 1:1.000.000



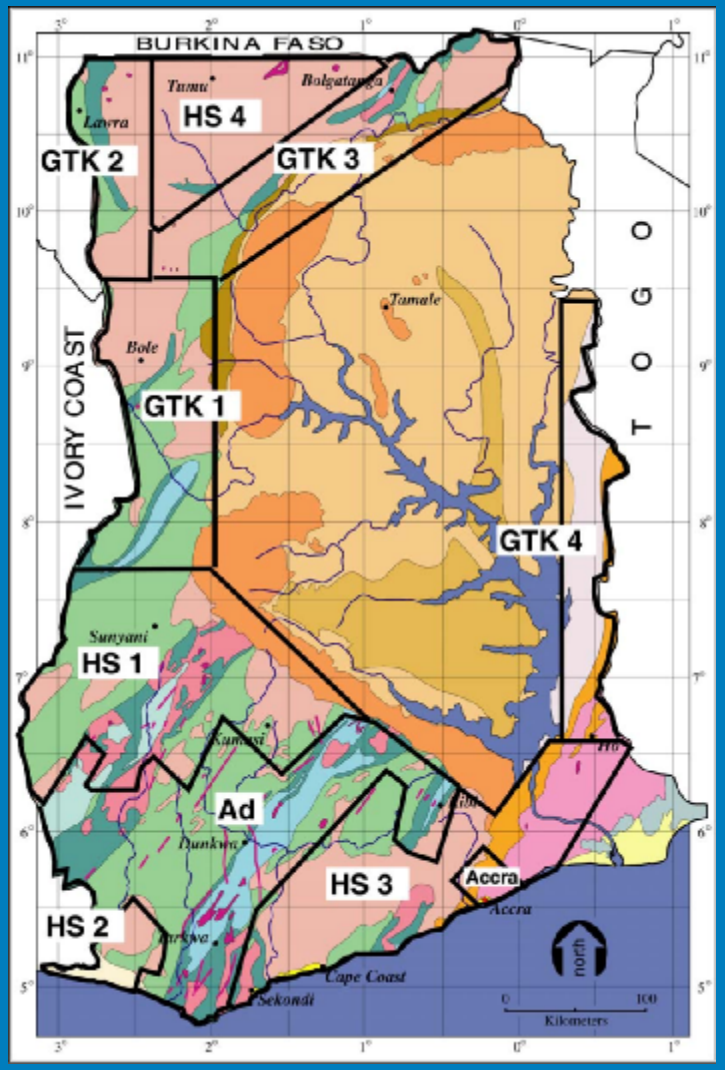


Source: Geological Map of Ghana, 2010
Geological Survey Department, Ghana
Bundesanstalt für Geowissenschaften und Rohstoffe, Germany

Case Study 1: Mineral Deposits (Ghana)

Input Data:
Airborne Geophysical Data

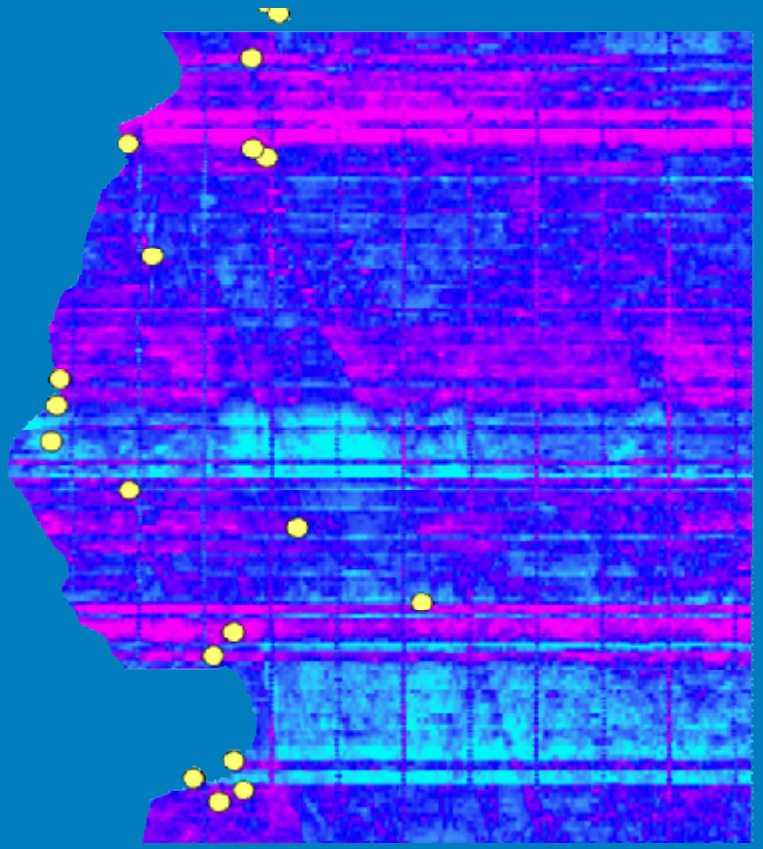
- Between 1996 and 1998, the World Bank/ Nordic Development Fund sponsored the Mining Sector Development and Environment Project.
- The EU funded MSSP has covered the Volta and Keta basins



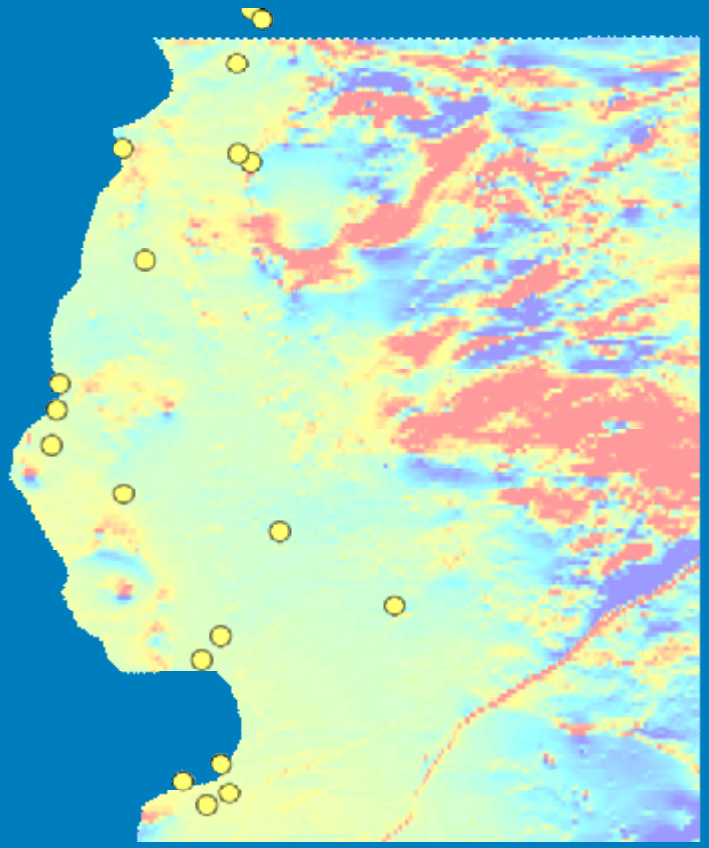
Source: Geological Survey Department of Ghana

Case Study 1: Mineral Deposits (Ghana)

Input Data:
Airborne Geophysical Survey - Electromagnetic



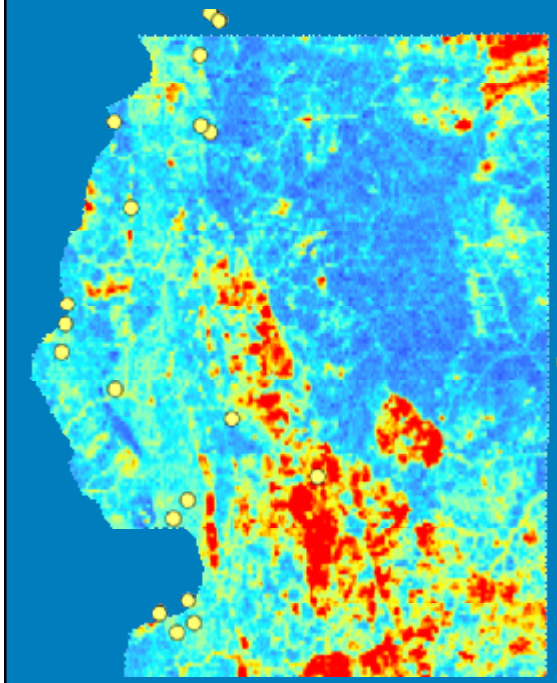
Input Data:
Airborne Geophysical Survey – Magnetic



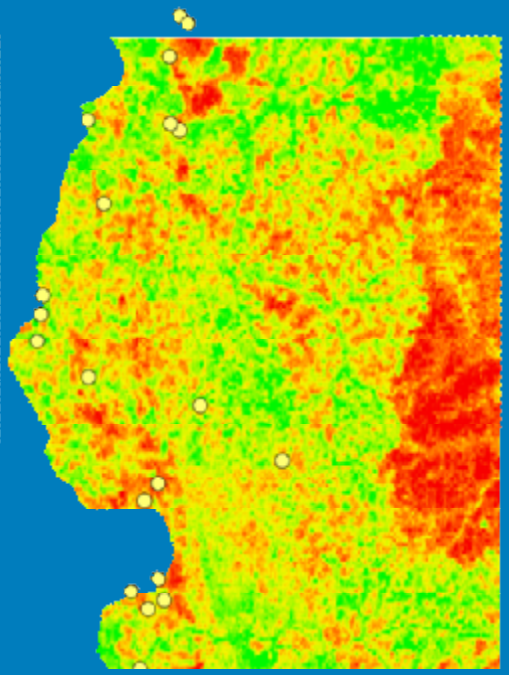
Source: Geological Survey Department of Ghana

Case Study 1: Mineral Deposits (Ghana)

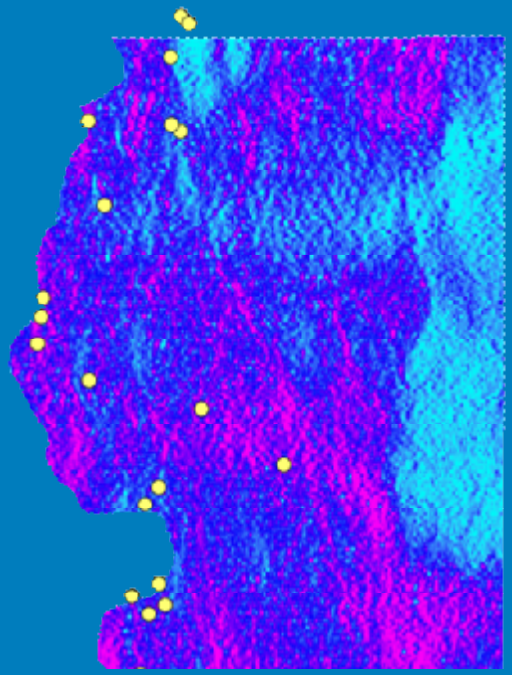
Input Data:
Airborne Geophysical Survey - Radiometric



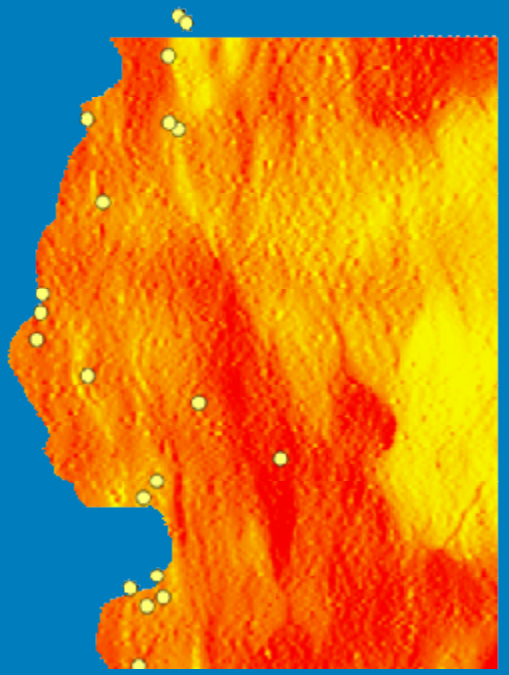
Potassium



Thorium



Uranium

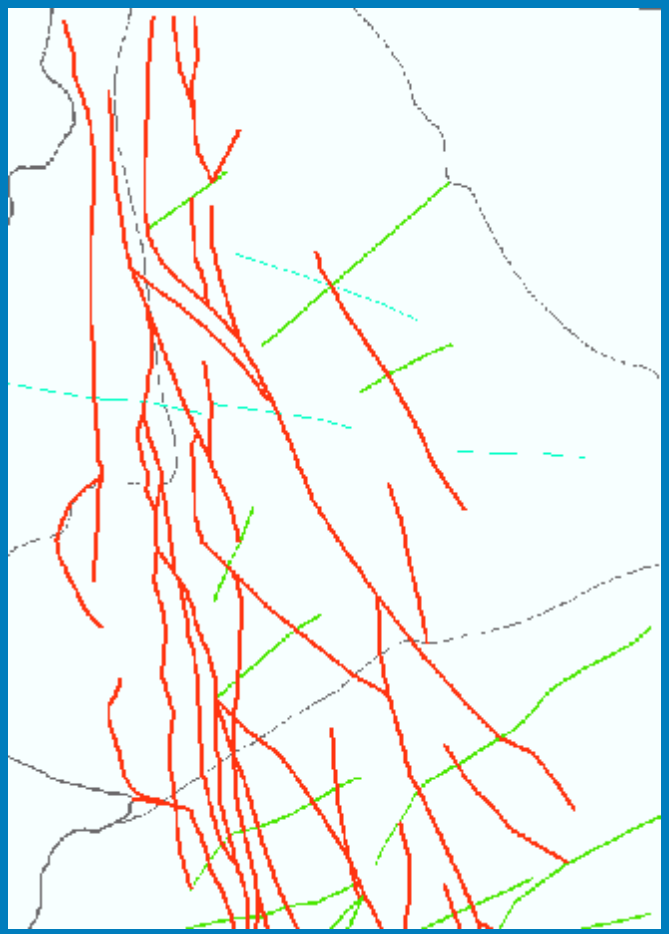


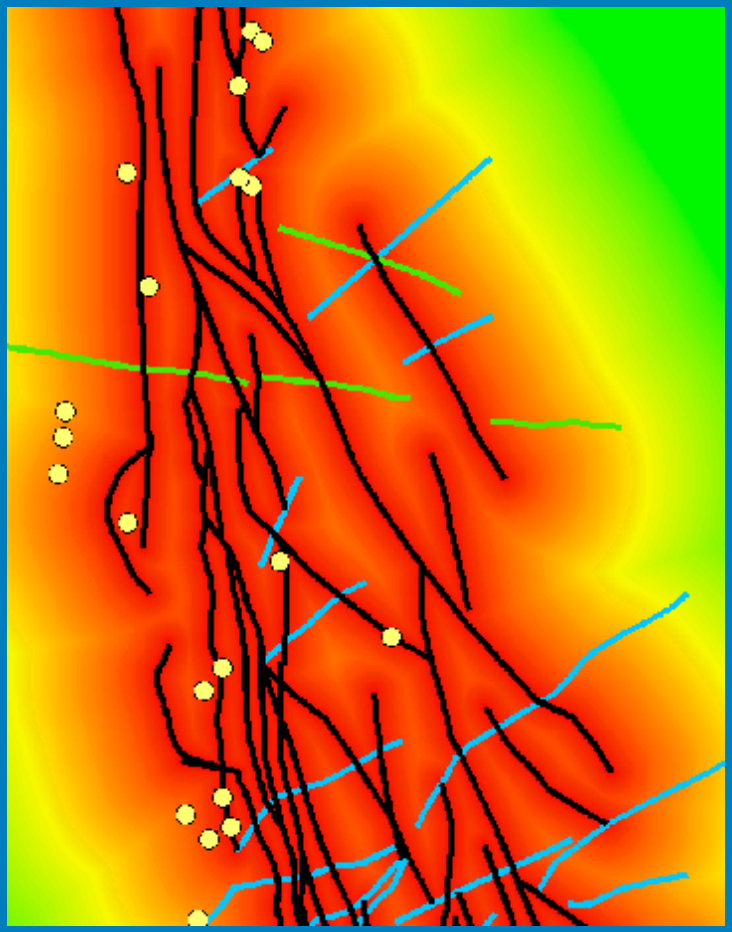
Total

Source: Geological Survey Department of Ghana

Case Study 1: Mineral Deposits (Ghana)

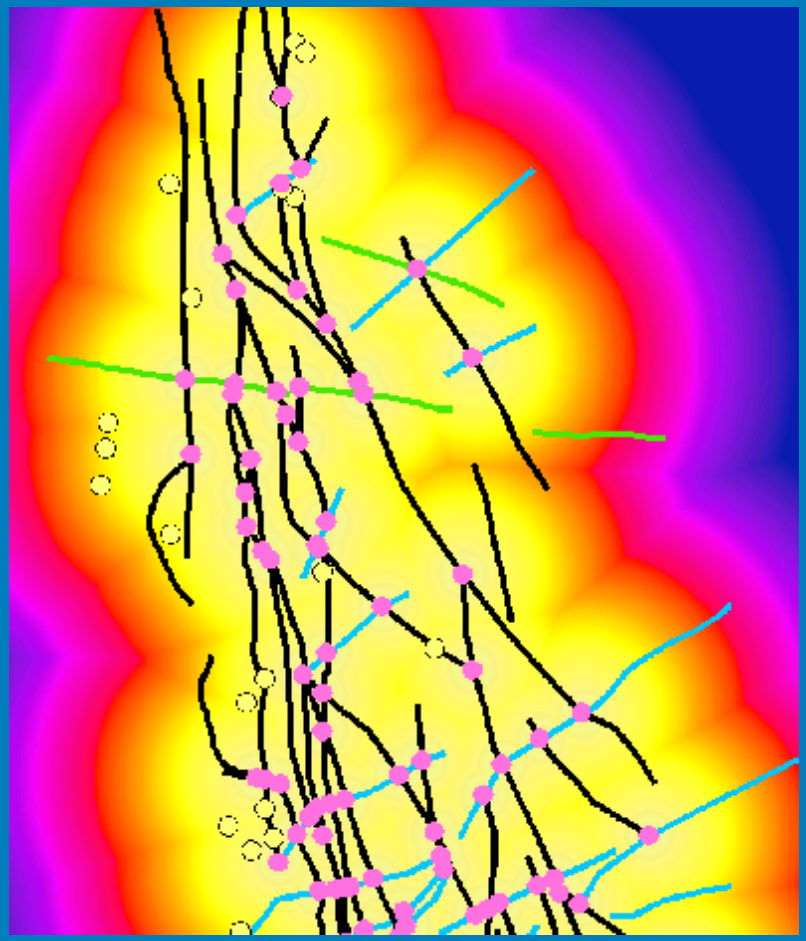
Input Data:
Euclidian Distance to Faults



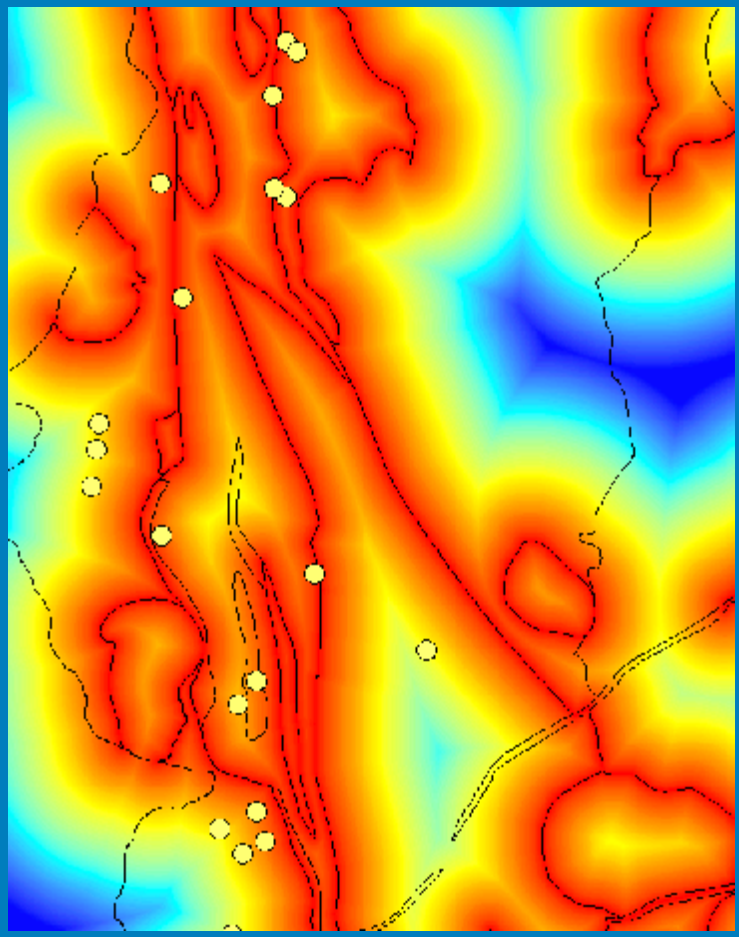


Case Study 1: Mineral Deposits (Ghana)

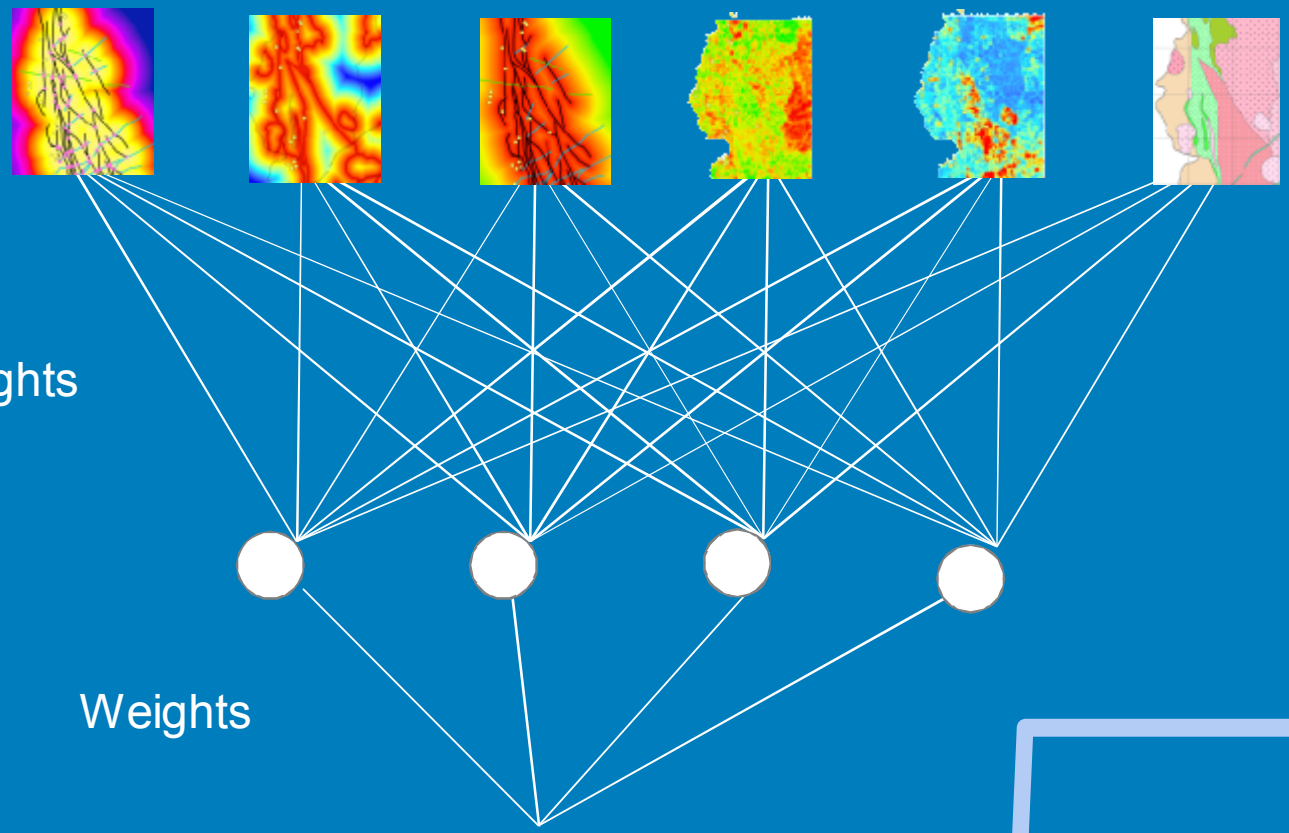
Input Data:
Euclidian distance to tectonic intersections



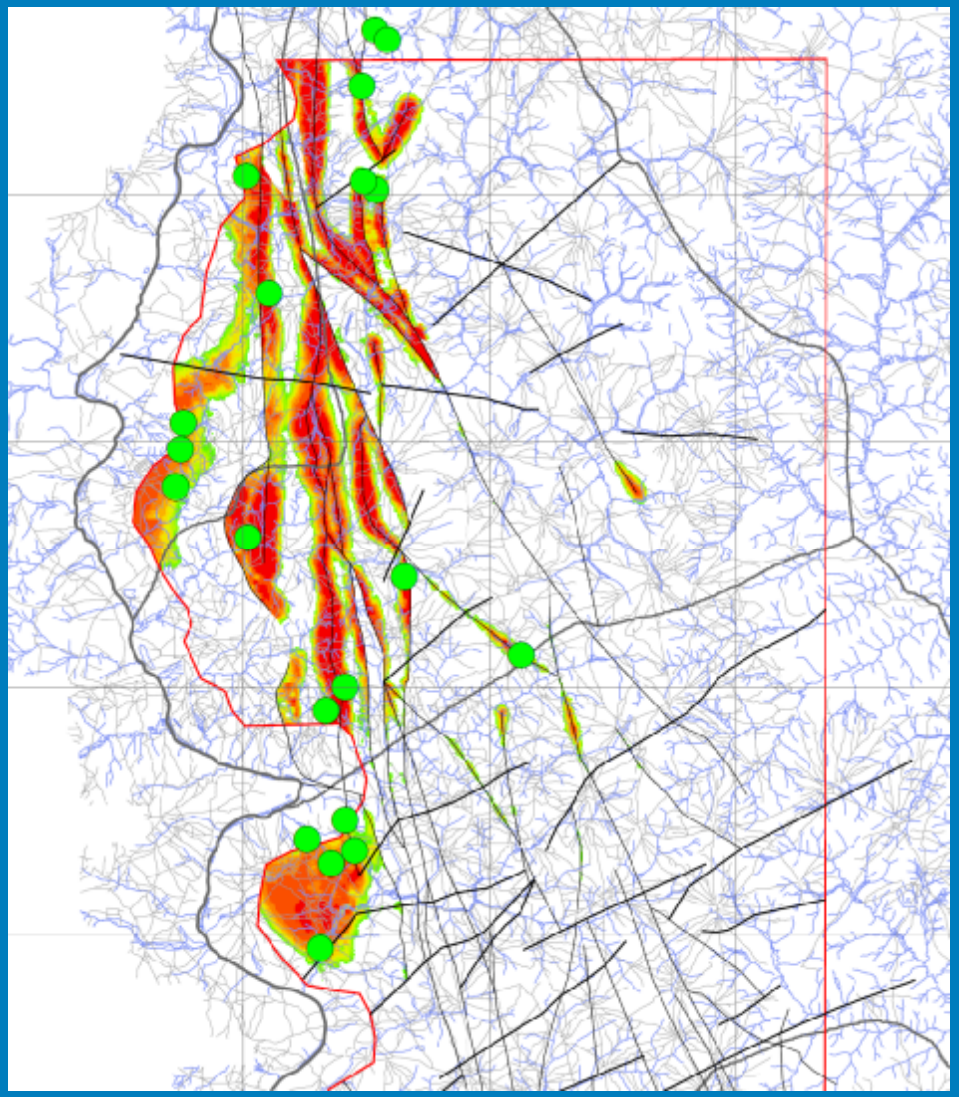
Input Data:
Euclidian distance to important rock contacts

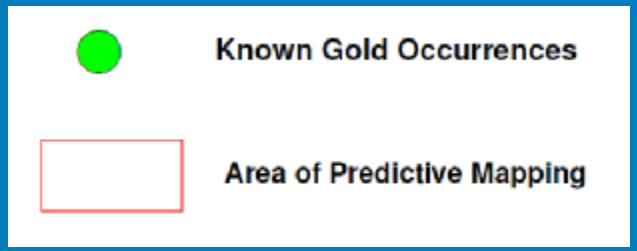


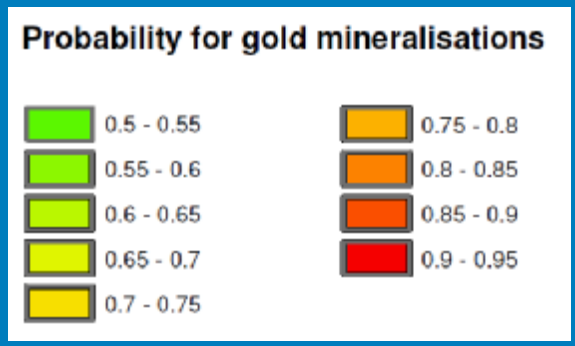
Case Study 1: Mineral Deposits (Ghana)



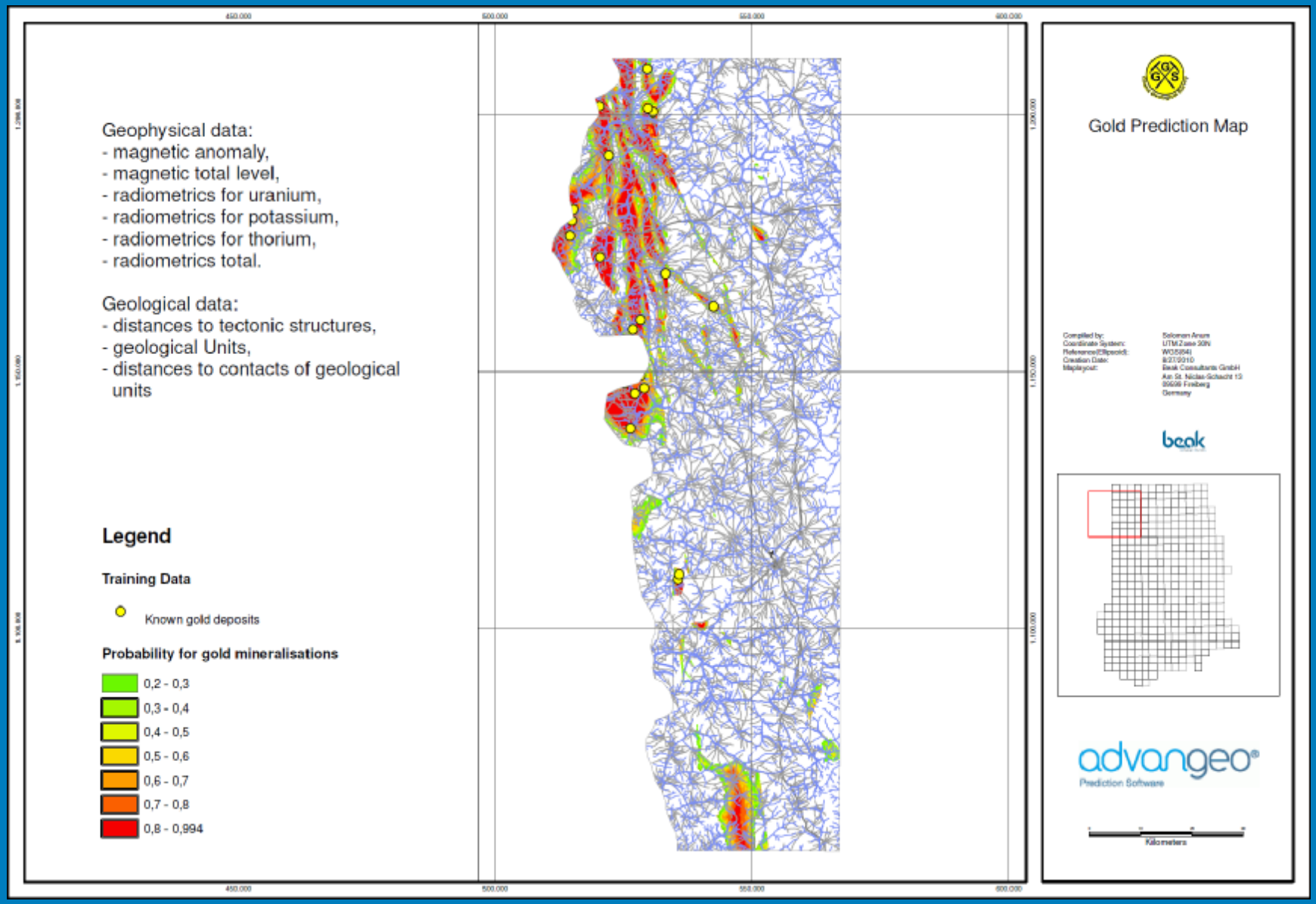
Case Study 1: Mineral Deposits (Ghana)



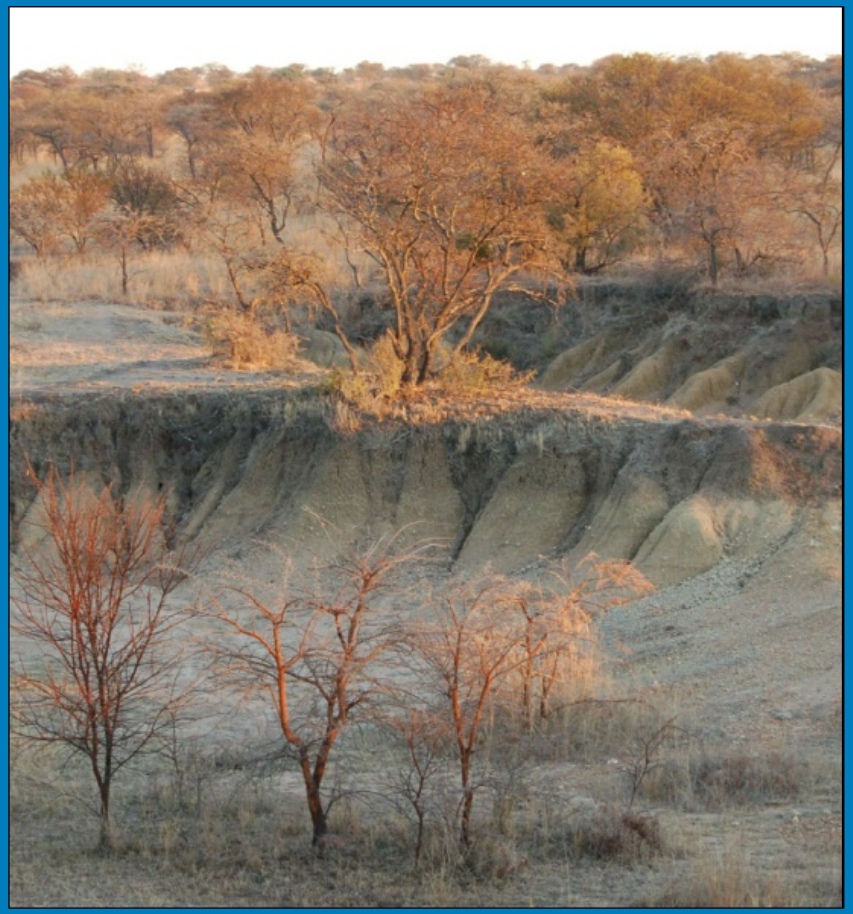




Case Study 1: Mineral Deposits (Ghana)



Where are erosion gullies formed?



Council for Geoscience

Modelling by:
Andreas Berger

Case Study 2: Erosion Gullies in Limpopo (South Africa)

Republic of South Africa

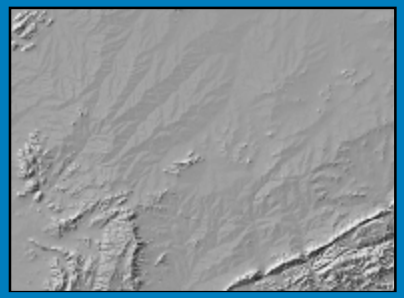
Limpopo Area

AEGOS

AFRICAN-EUROPEAN GEORESOURCES OBSERVATION SYSTEM

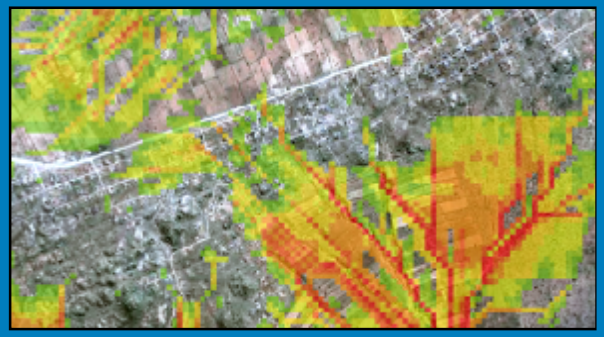
Case Study 2: Erosion Gullies in Limpopo (South Africa)

Input Data:
Elevation Model and its Derivates
Geological Map
Landuse



Trainings Data:
Observed Erosion Gullies from Aerial Images

advangeo®
Prediction Software



Case Study 2: Erosion Gullies in Limpopo (South Africa)

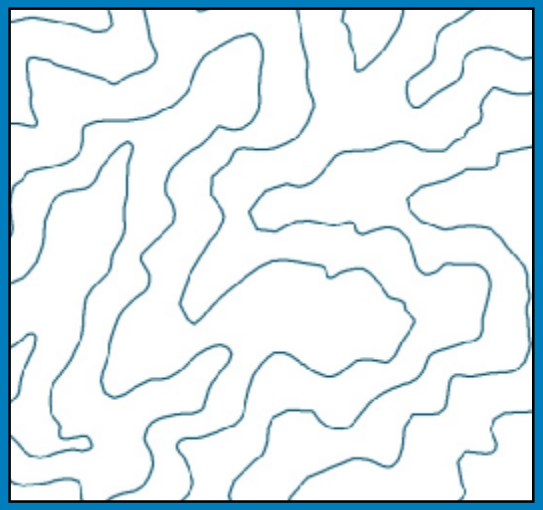
Available Data and Knowledge

- Digital terrain model (DTM)
  - Contour lines from Topographical maps: resolution depending on scale
  - ASTER GDEM: 30 m resolution
  - SRTM: 90 m resolution
- Derivates of the DTM
  - Slope,
  - Flow accumulation,
  - Flow length,
  - Slope contour (curvature)
- Landuse information
- Known erosion sites for training → taken from satellite images → Google Earth data

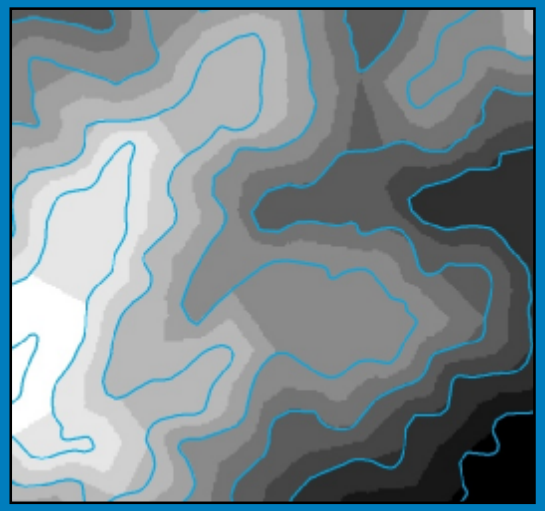
Case Study 2: Erosion Gullies in Limpopo (South Africa)

Input Data: *Contour Lines*

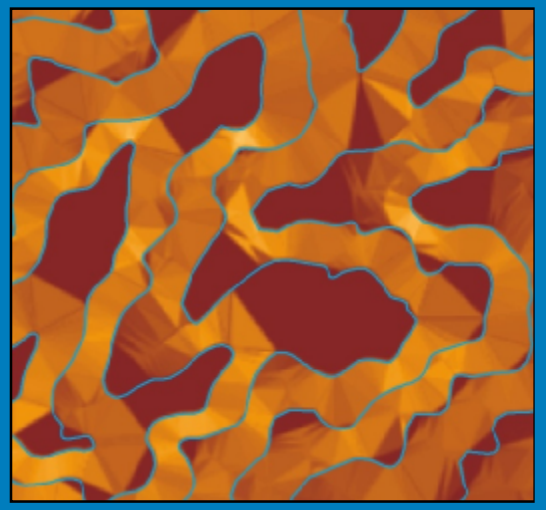
- Created by digitalization of topographic maps
- Conversion to elevation grid (method: triangulation)
  - Problem: generates areas of equal elevation and stair-like sections



20 m elevation contour lines



Elevation grid



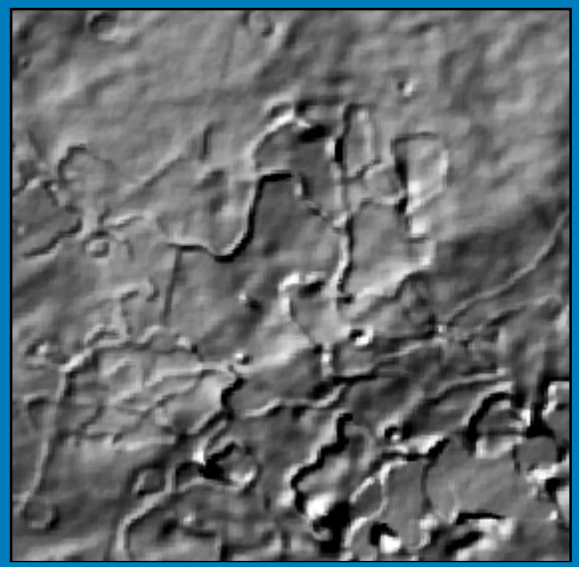
Slope grid

→ **The contour line generated DTM is not suitable for erosion modelling**

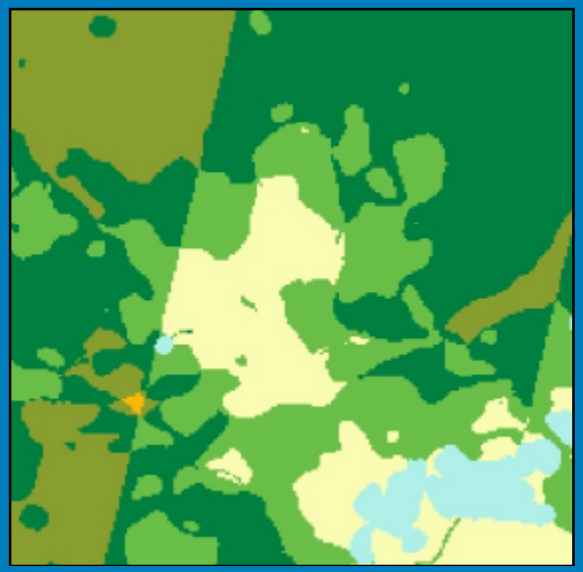
Case Study 2: Erosion Gullies in Limpopo (South Africa)

Input Data: *ASTER GDEM*

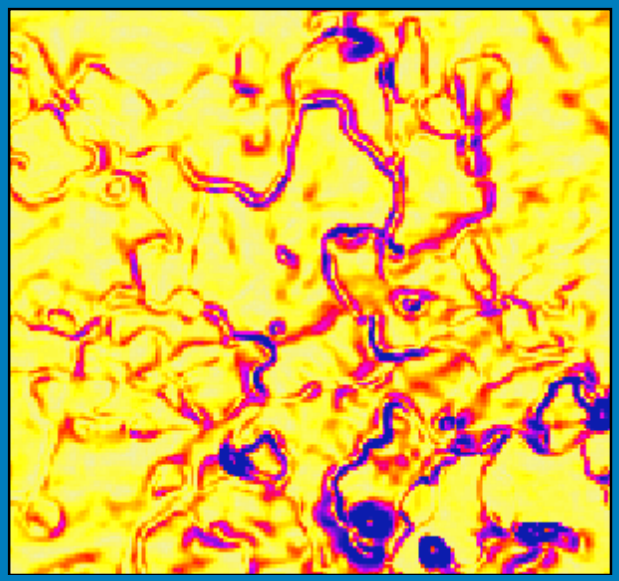
- Problem: variety of pervasive artifacts related to linear and curvilinear boundaries between different scene-based ASTER-DEMs (stack number)
- Artifacts appear as different geometric shapes and associate anomalous elevations (range from 1 m to more than 100 m)
- Usability can be reduced for certain applications (prediction of erosion) because of possible large elevation errors on local scale



ASTER GDEM hill-shade image



Boundaries of stack number areas (1 colour = 1 stack number)

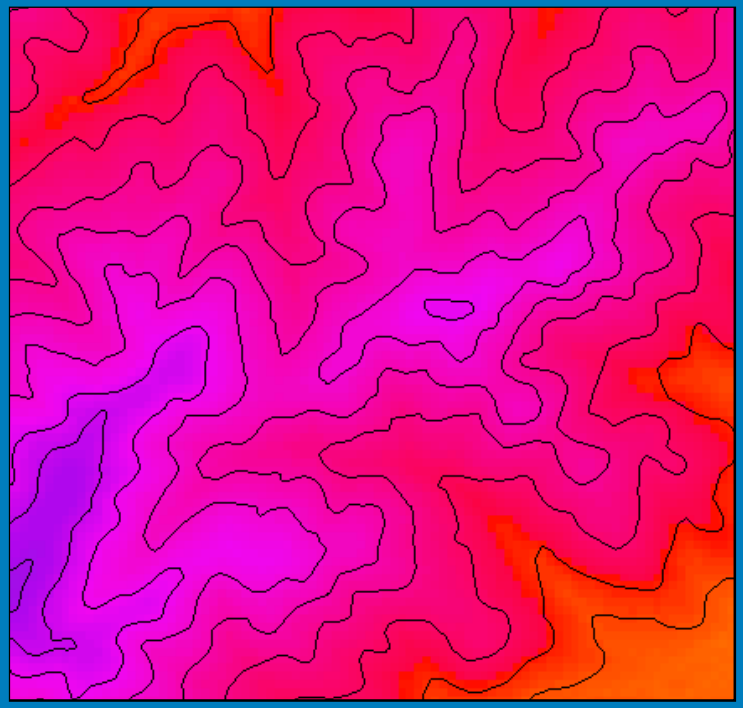


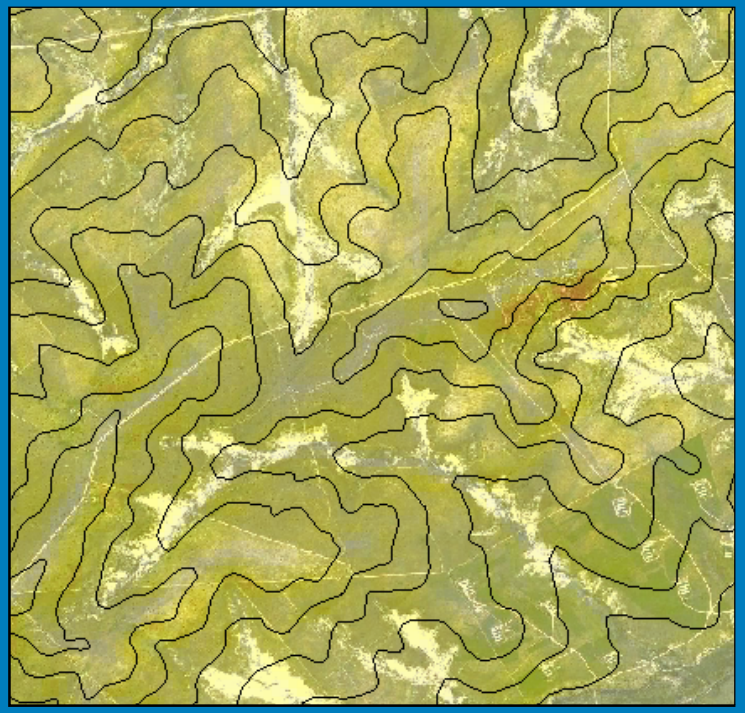
Slope angle

Case Study 2: Erosion Gullies in Limpopo (South Africa)

Input Data: *SRTM*

- Good fitting to the local elevation model
- No important inconsistencies have been observed so far
- Problem: Low resolution: 90 m → resolve it to 30 m





Case Study 2: Erosion Gullies in Limpopo (South Africa)

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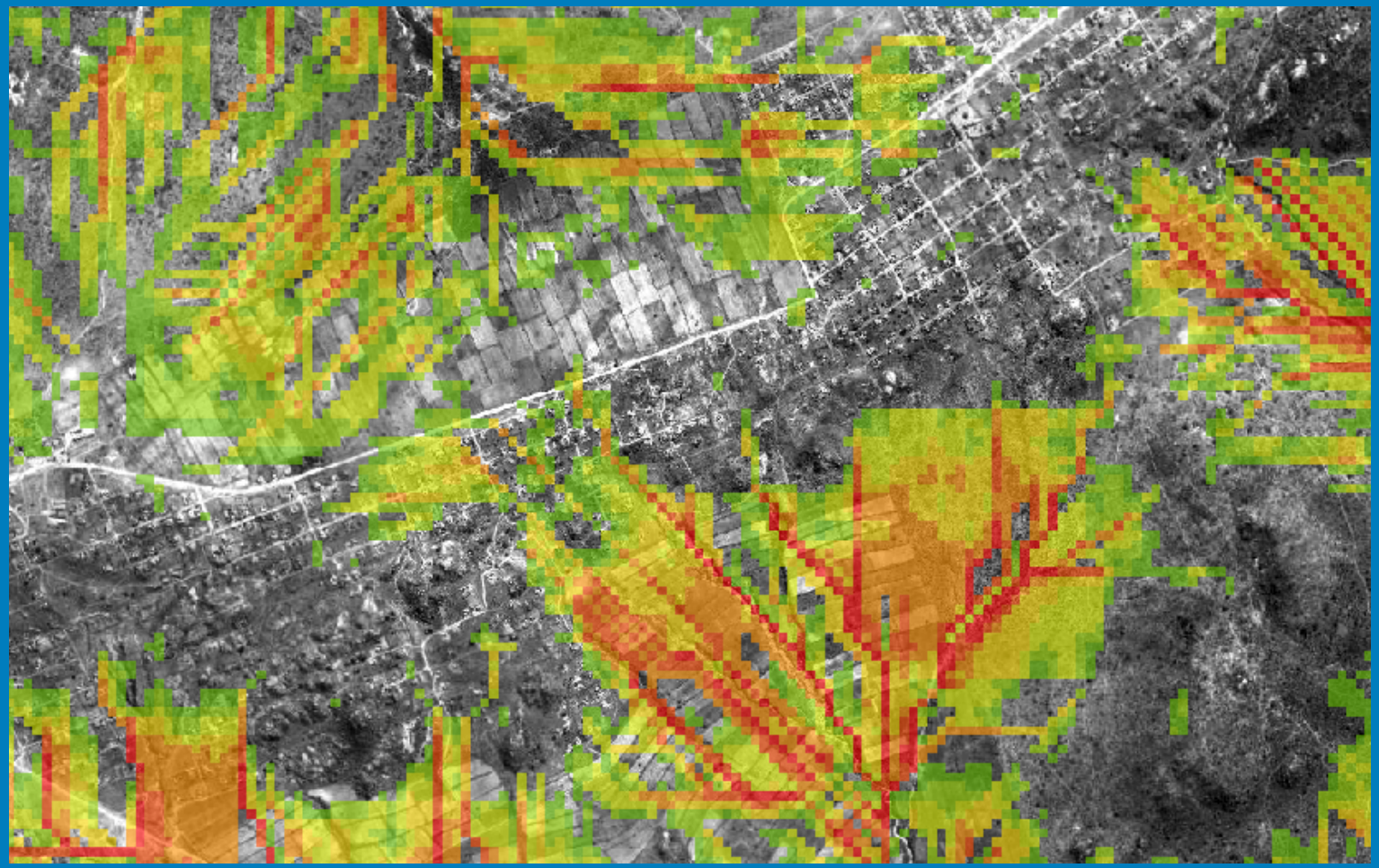
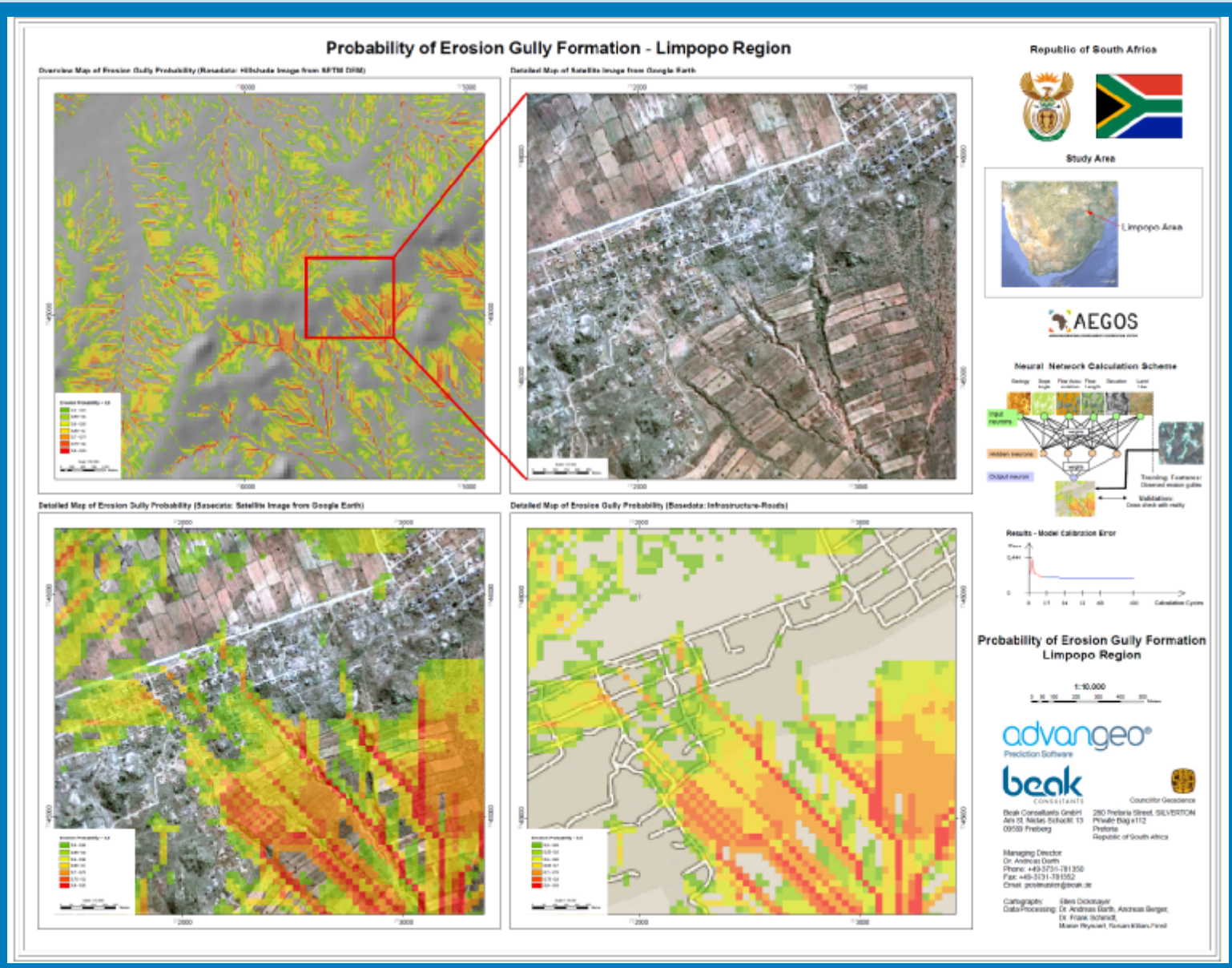


Case Study 2: Erosion Gullies in Limpopo (South Africa)

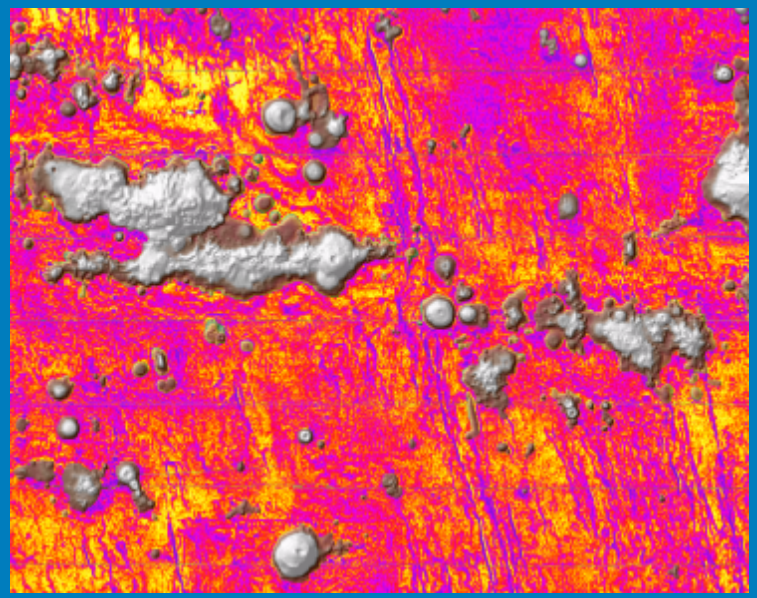


Further Case Studies

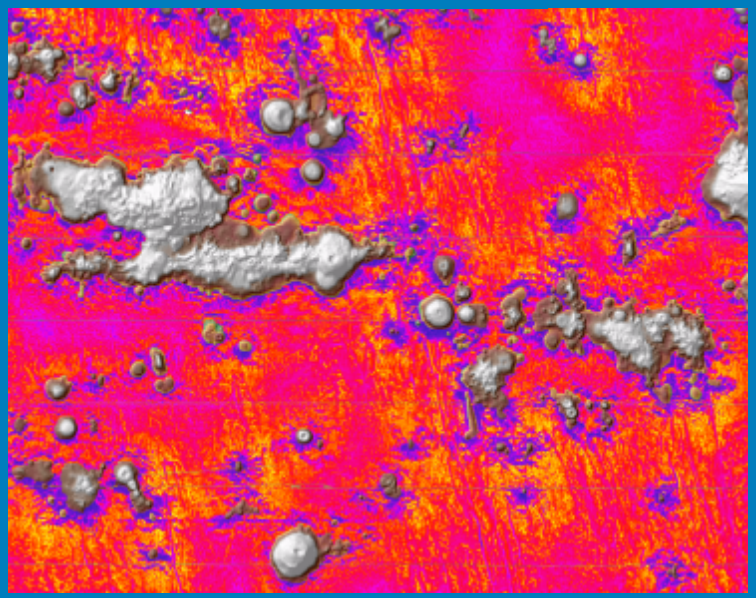
- **Manganese Nodules Coverage Density**: Clarion-Clipperton Zone / Pacific Ocean (BGR, 2010)
- **Mineral Deposits / Occurrences - Pb/Zn, Au, Cr**: Kosovo (ICMM, 2003 – 2009)
- **Coal Fires**: China (TUBAF, 2010)
- **Clay Mineral Classification**: Burkina Faso (Vaclav Metelka, 2010)
- **Extensive Soil Erosion**: Freital / Germany (2009)
- **Soil Creeping**: Freital / Germany (2009)
- **Formation of Erosion Gullies**: Freital / Germany (2009)
- **Soil Contaminations in Urban Areas**: Marienberg / Germany (LfULG, 2010)
- **Spread of Forest Pests**: Tharandter Wald / Germany (Sachsenforst, 2009)

Further Case Studies: Manganese Nodules Coverage Density (CCZ)

Model 1



Model 2

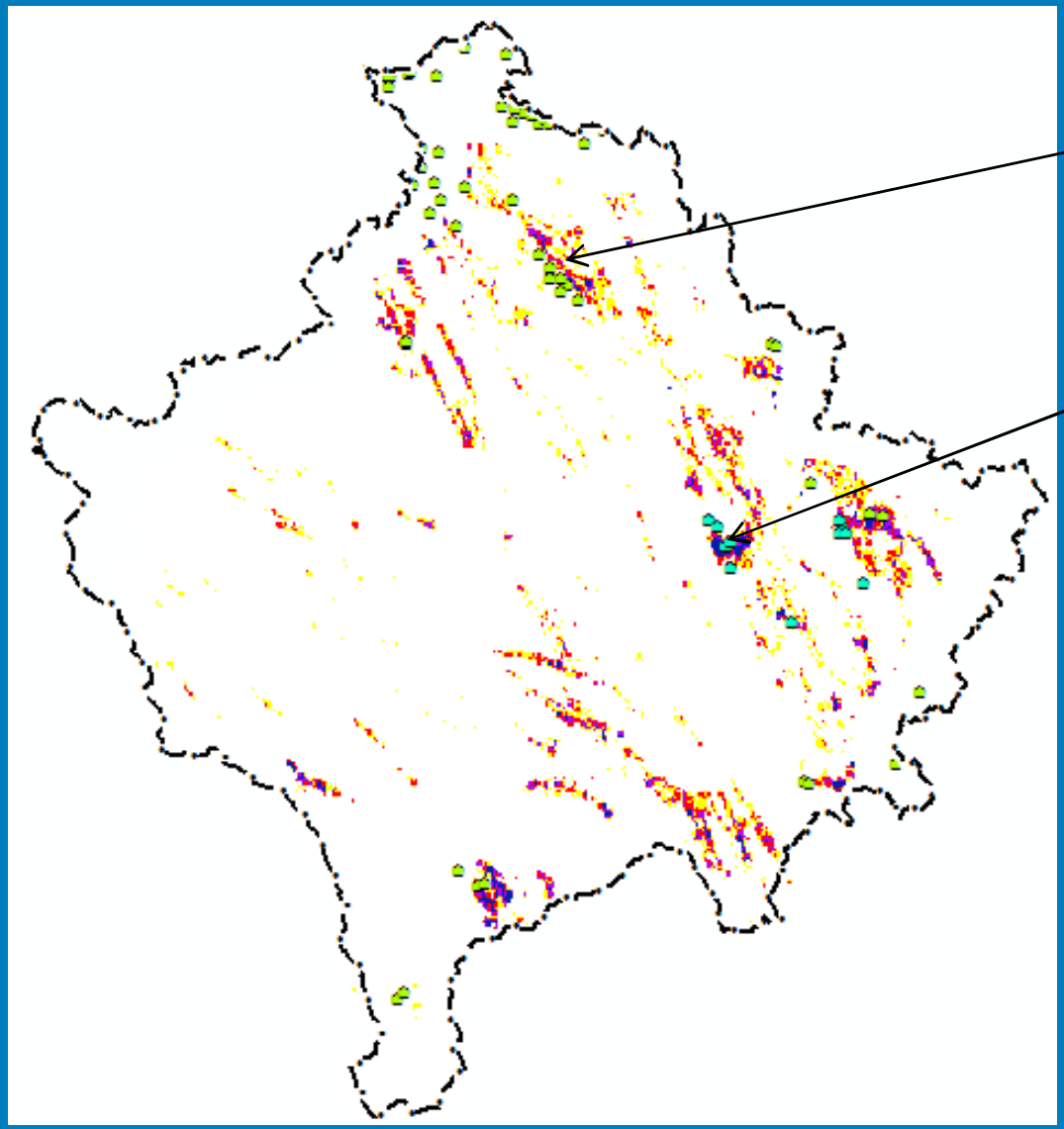


Manganese Nodule Coverage Density

high

low

Further Case Studies: Mineral Deposits (Kosovo)



Test Points

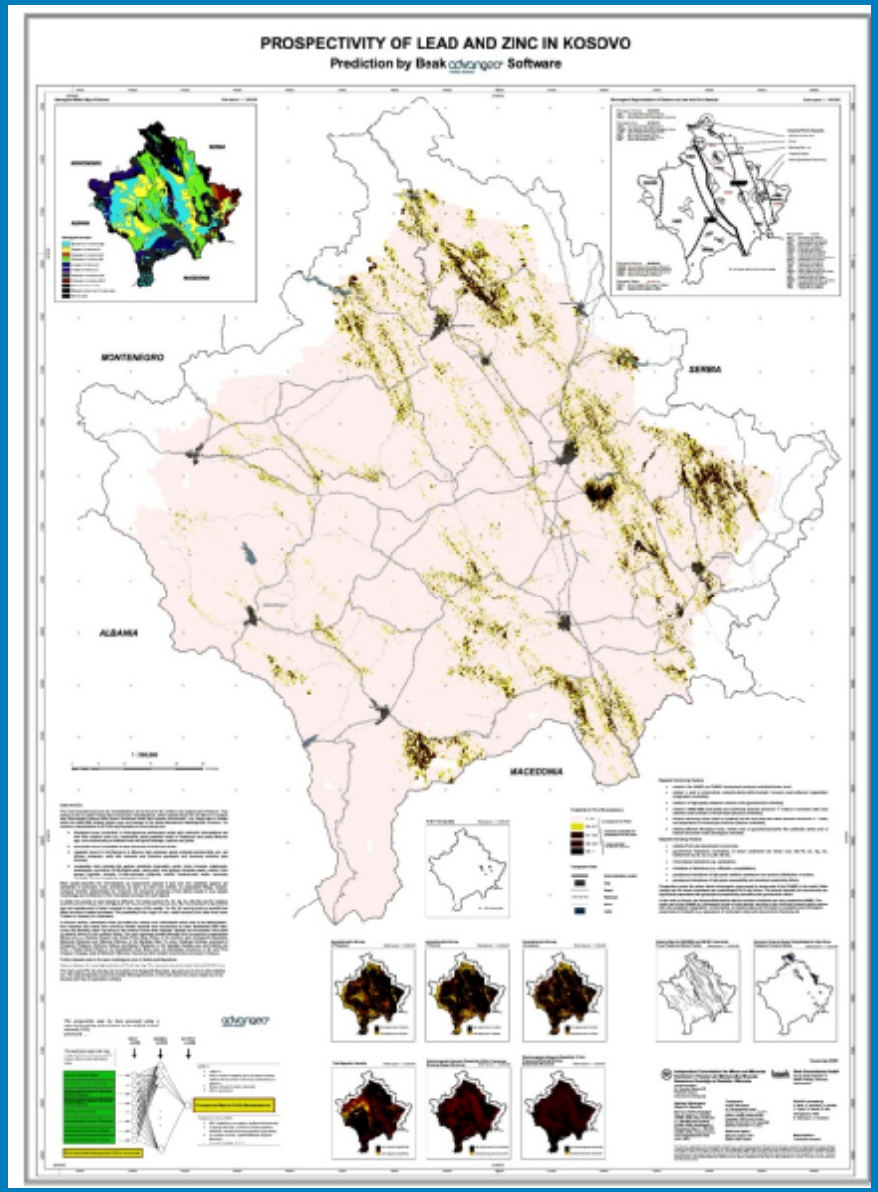
Training Data

Training Points

Probability for Pb-Zn Mineralisations

0 - 0,5	no response for Pb-Zn
0,5 - 0,7	moderate probability for prospective Pb-Zn areas
0,7 - 0,8	
0,8 - 0,9	most potential for Pb-Zn deposits
0,9 - 1	

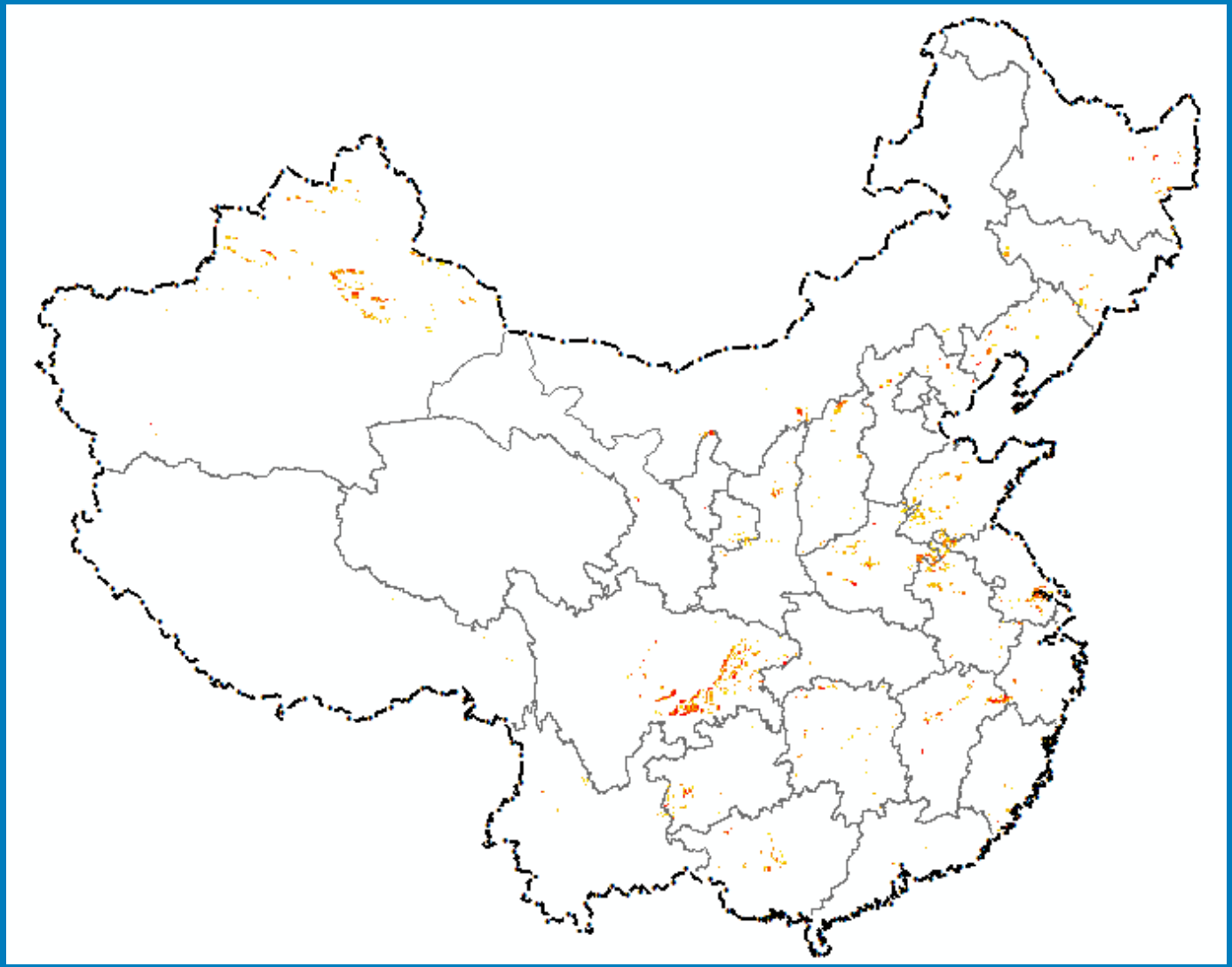
Further Case Studies: Mineral Deposits (Kosovo)



Prospectivity Maps of Kosovo at scale 1:200,000 have been compiled / are available for:

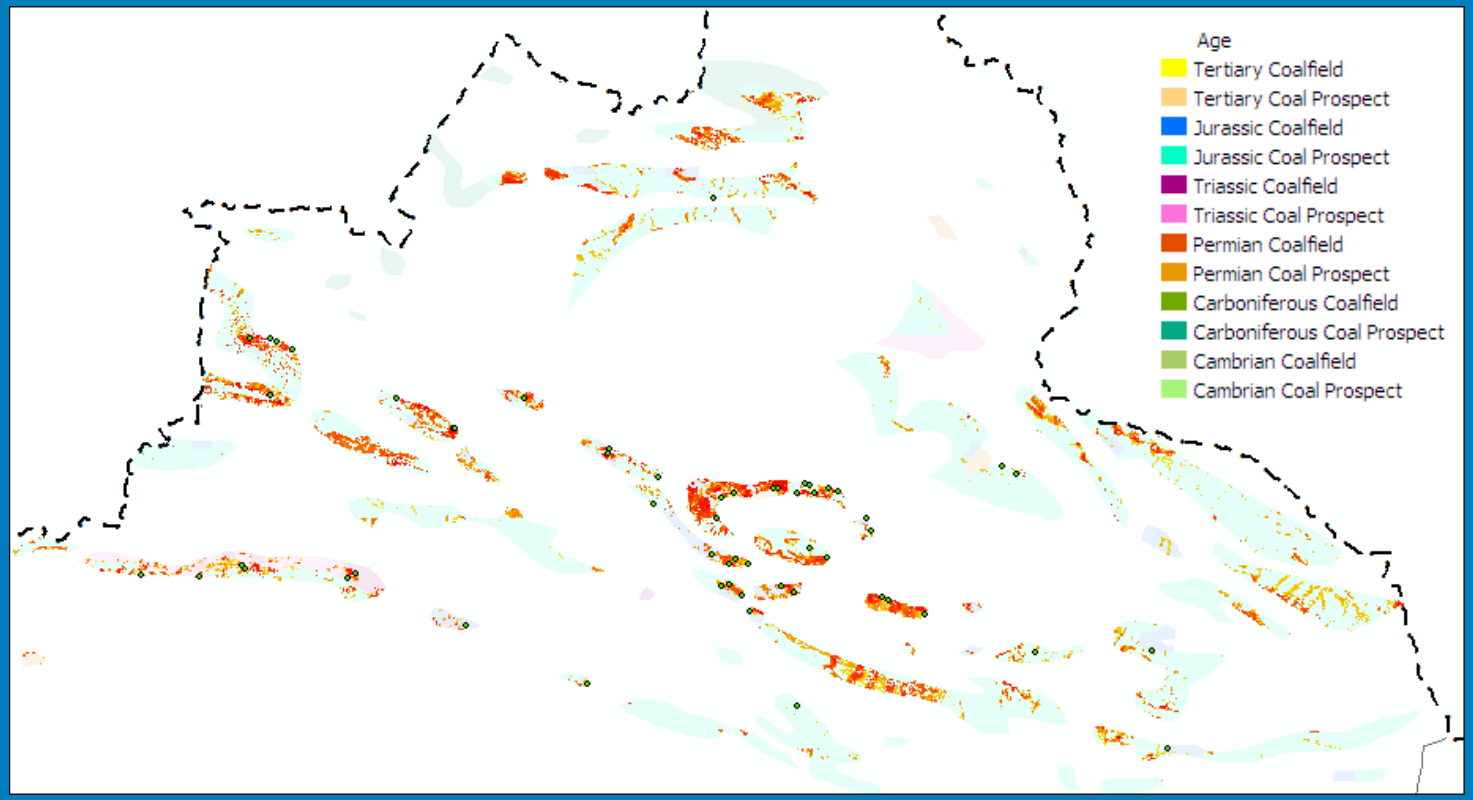
- Pb/Zn
- Au
- Cr

Further Case Studies: Coal Fires (China)



Further Case Studies: Coal Fires (China)

Detail Map: Northern Xinjiang Province



Coal Fire Probability

- 0 - 0,55
- 0,55 - 0,6
- 0,6 - 0,65
- 0,65 - 0,7
- 0,7 - 0,75
- 0,75 - 0,8
- 0,8 - 0,85
- 0,85 - 0,9
- 0,9 - 0,95
- 0,95 - 1

Summary / Outlook

- **AEGOS** provides infrastructure to execute innovative projects based on existing / available geodata
- Multiple applications of the developed methodology using artificial neural networks and GIS with **advangeo®** in geosciences
- **Currently in development:**
  - ***Soil Parameter Regionalisation Model***
  - ***Mineral Deposit Prediction Model***

→ **We look forward to your questions, suggestions and comments and hope for future knowledge sharing and collaboration!**

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