# Mineral Prospectivity Evaluation by Artificial Neural Networks and GIS

Methodology, Case Studies, Experiences

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**Global Geospatial Conference (GSDI) / AfricaGIS 2013**
**Addis Ababa**
**04/11/2013**

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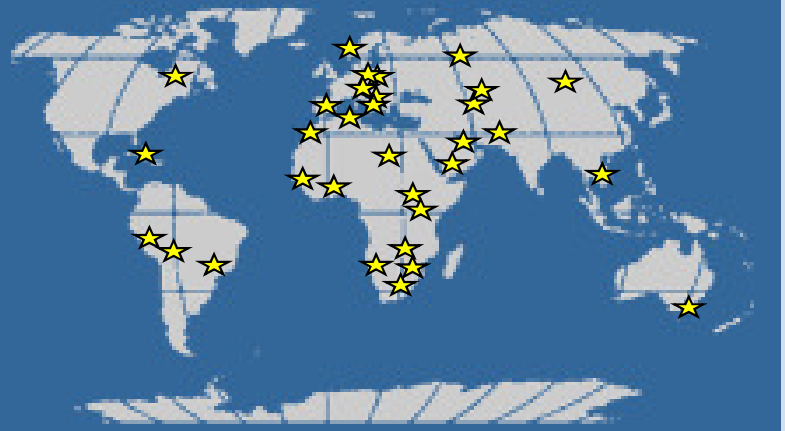
# Beak Consultants GmbH

- **Fields of business**
  - Geology, exploration, environment
  - GIS and cartography
  - Tailor-made software

- **ISO 9001:2008 certificate**



- **19 years of company experience**

- **Roots are the**
  - East German Geological Survey
  - Canadian Beak Consultants International

- **Activities in Africa:**
  - Databases and GIS
  - Mineral exploration targeting
  - Data processing

AEGOS
AFRICAN-EUROPEAN GEORESOURCES OBSERVATION SYSTEM

# Approaches of Predictive Mapping

- **Data driven:**
  - **Artificial neural networks**
  - Logistic regression
- **Knowledge driven:**
  - Fuzzy logic
  - Weights of evidence
  - Simple summarizing of relevant information

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Prediction Software

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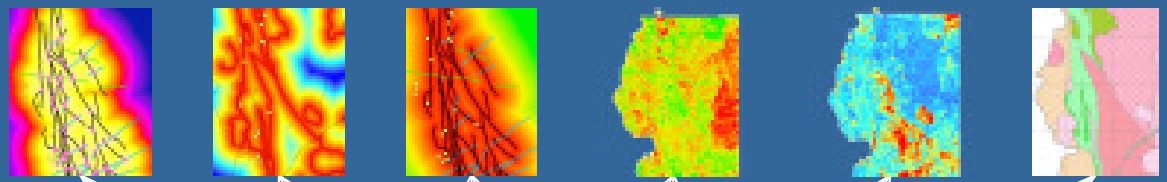
# Using Artificial Neural Networks

**Input Data / Layer**

Tectonics | Geophysics | Geochemistry | Geology



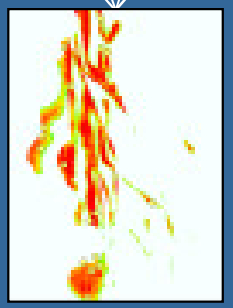
Weights

**Hidden Layer**

Weights

**Output Layer**

Shows favorabilities for detection of mineralisations



**Predictive Map**

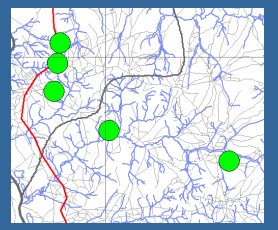
**TRAINING**

RMS

Iterations

**VALIDATION**

**Training Data**



Known Mineralisations

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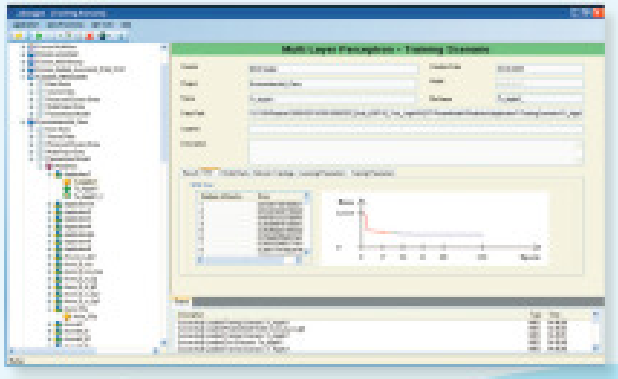
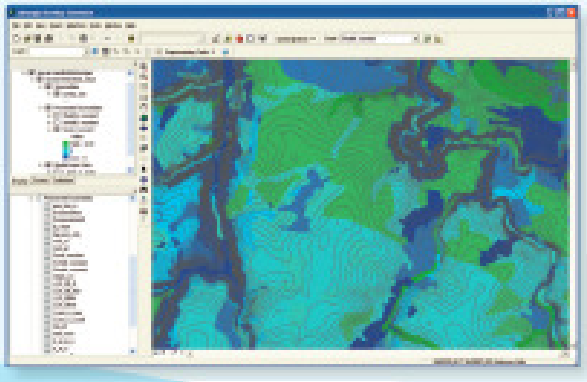
# advangeo® Software Structure

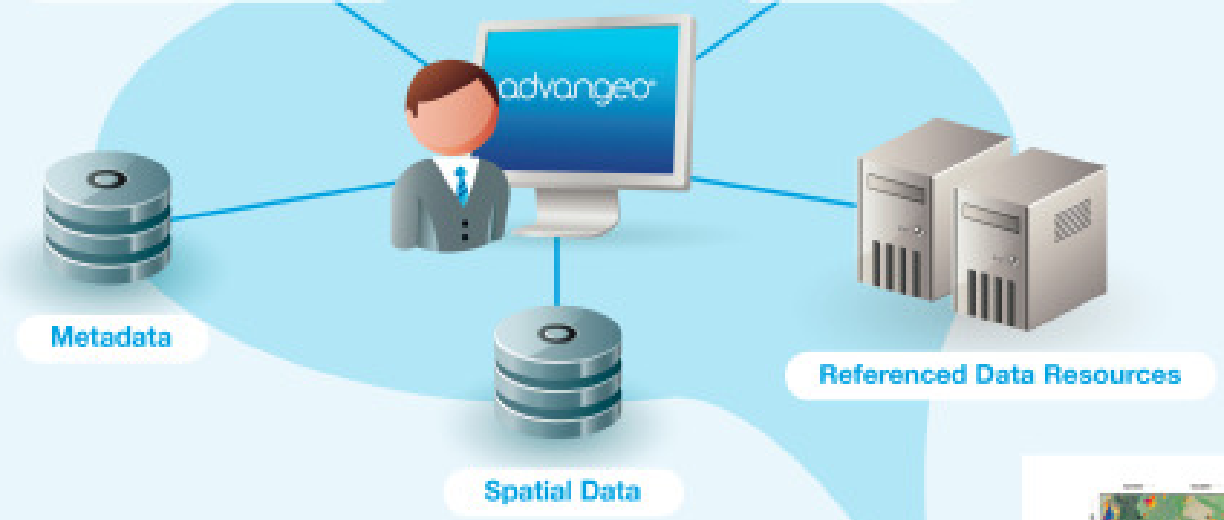


Data and Model Explorer



GIS Extension

ArcGIS ESRI

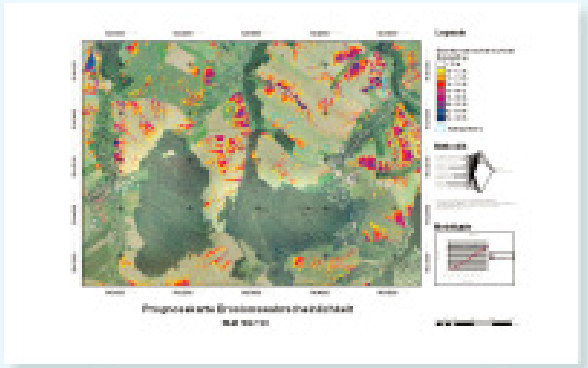



Metadata

Referenced Data Resources

Spatial Data

advangeo's components



Prediction Presentation

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# Agenda

- **Mineral Predictive Mapping**
  - Case Study 1
    - *Topic:*
      - Gold in Hard Rocks / Placers in SW-Ghana
    - *Project Partner:*
      - Geological Survey Department of Ghana
      - TU Bergakademie Freiberg
  - Case Study 2
    - *Topic:*
      - Niobium-Tantalum / Gold in Rwanda
    - *Project Partner:*
      - Rwanda Natural Resources Authority
      - Ministry of Natural Resources

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# CASE STUDY 1: Gold in South-West Ghana

- Prime product of Ghana for thousands of years
- Annual production reaches 134 t (2012)
- Income for millions of people

- Destroys landscapes
- Consumes land
- Competes with other land use
- Creates conflicts

**Mineral Predictive Maps**

- Safe exploration funds
- Attract more investment
- Guide the industry and ASM
- Foresee and manage land use conflicts
- Protect resources & environment
- Improve infrastructure planning

# How to Build a Predictive Model?

❶ Definition of Model Accuracy / Resolution and Extent

❷ Selection and Harmonization of Source Data

❸ Processing of Source Data

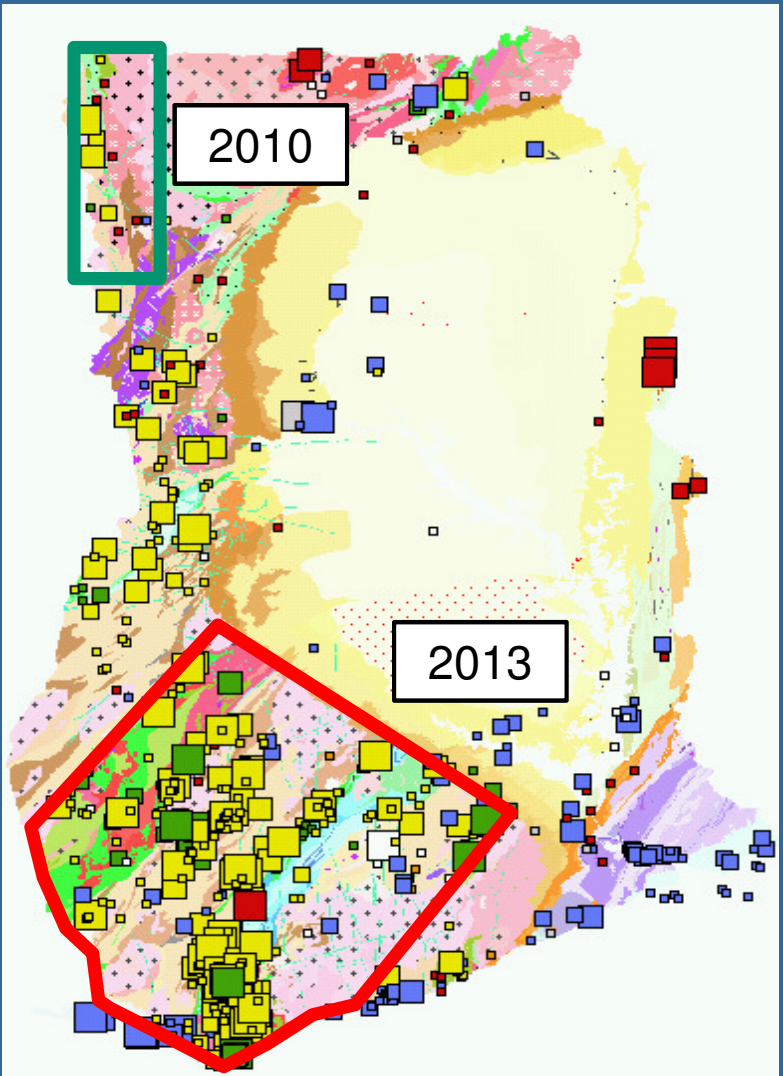
❹ Preparation of Model Input Data

❺ Setting Up and Running of Different Model Scenario

❻ Presentation of Final Model Scenario Results

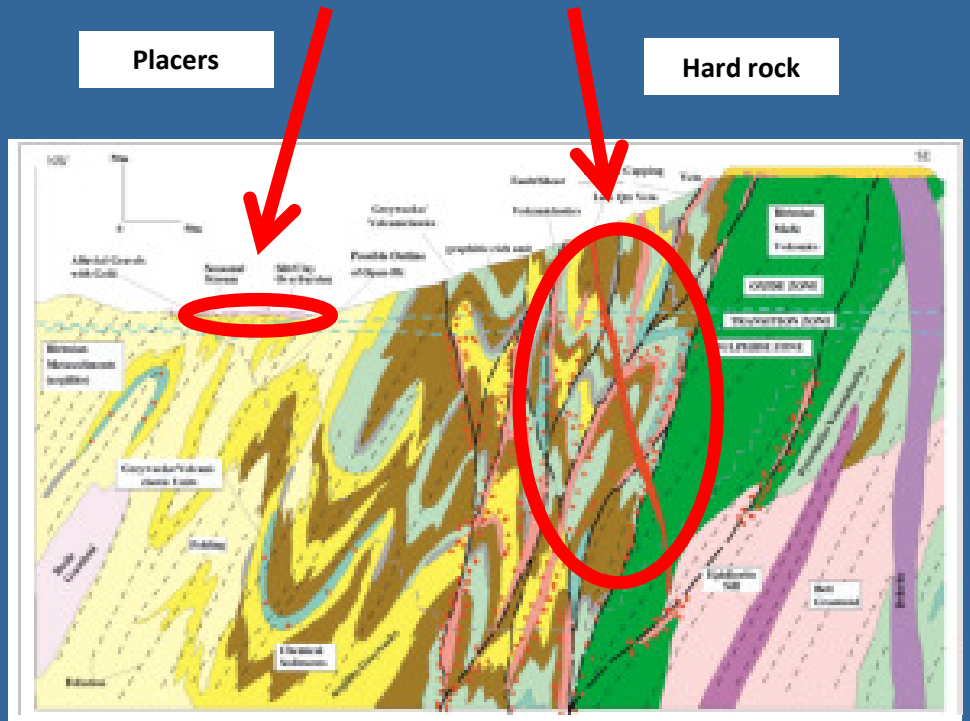
# Project Area & Genetic Model

## Investigation Areas




Source: The Geological Survey Department, Ghana

## Genetic types of gold deposits




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

Gold deposits

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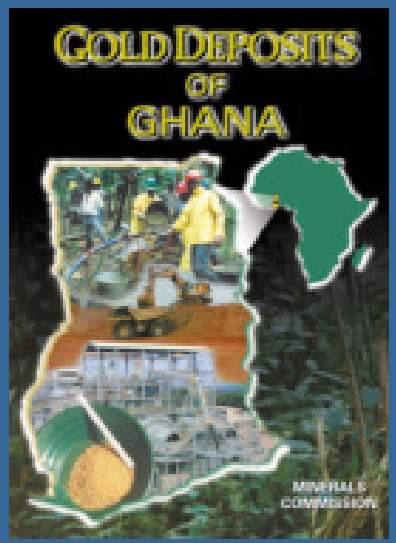
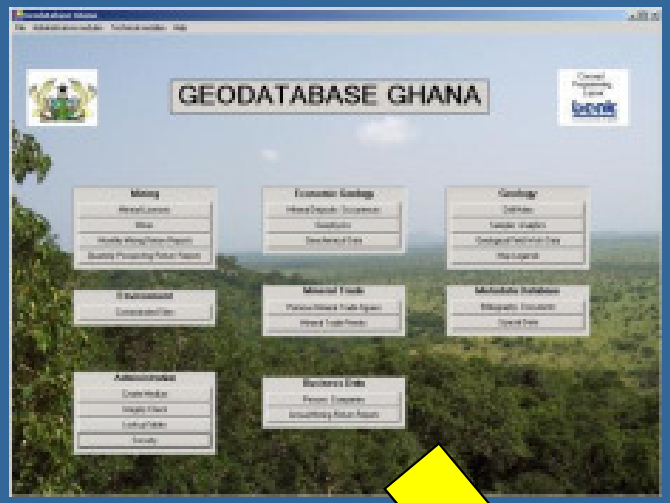
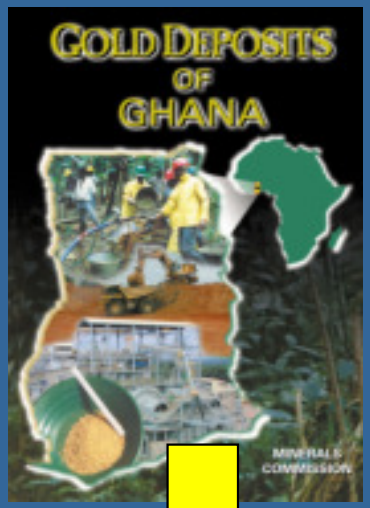
# Available Base Data

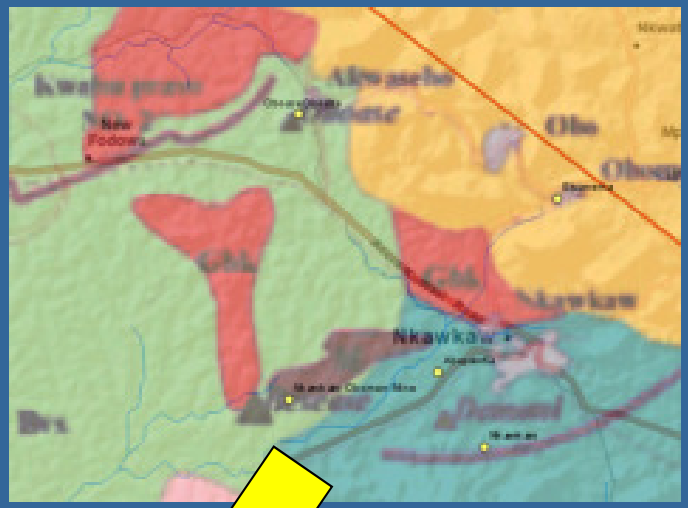
- **Geodatabase Ghana ( created during the MSSP 2005 – 2009 ):**
  - Geological maps ( 1:50,000 – 1:1,000,000 )
  - Tectonic maps
  - Geophysical data
  - Mineral occurrence data
- **Additional information:**
  - Published literature



# Harmonizing Gold Occurrence Data




## Project database attributes:

- Exact location
- Genetic type
- Host rocks
- Ressources
- Size
- Producer

- 340 vein/stockwork deposits/occurrences
- 40 placers
- 30 unclear (excluded)

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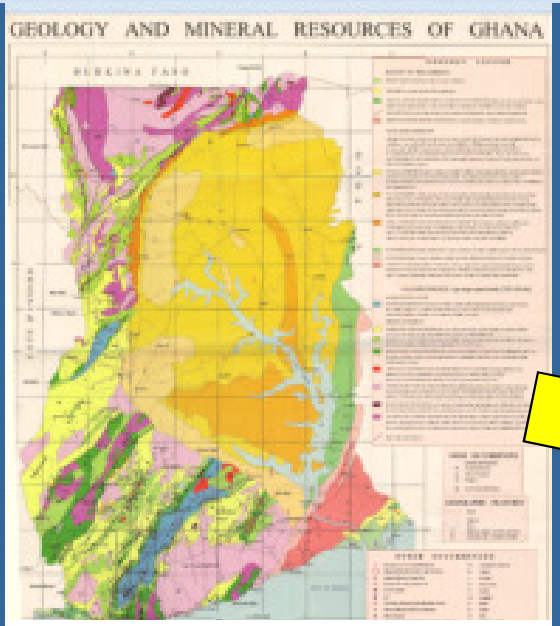
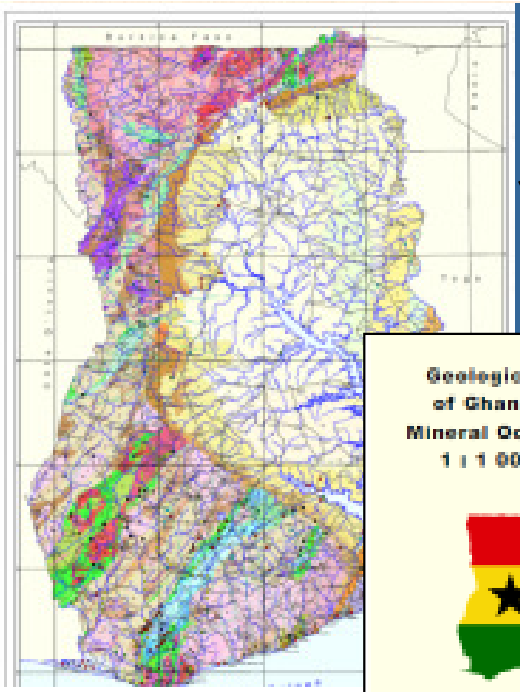
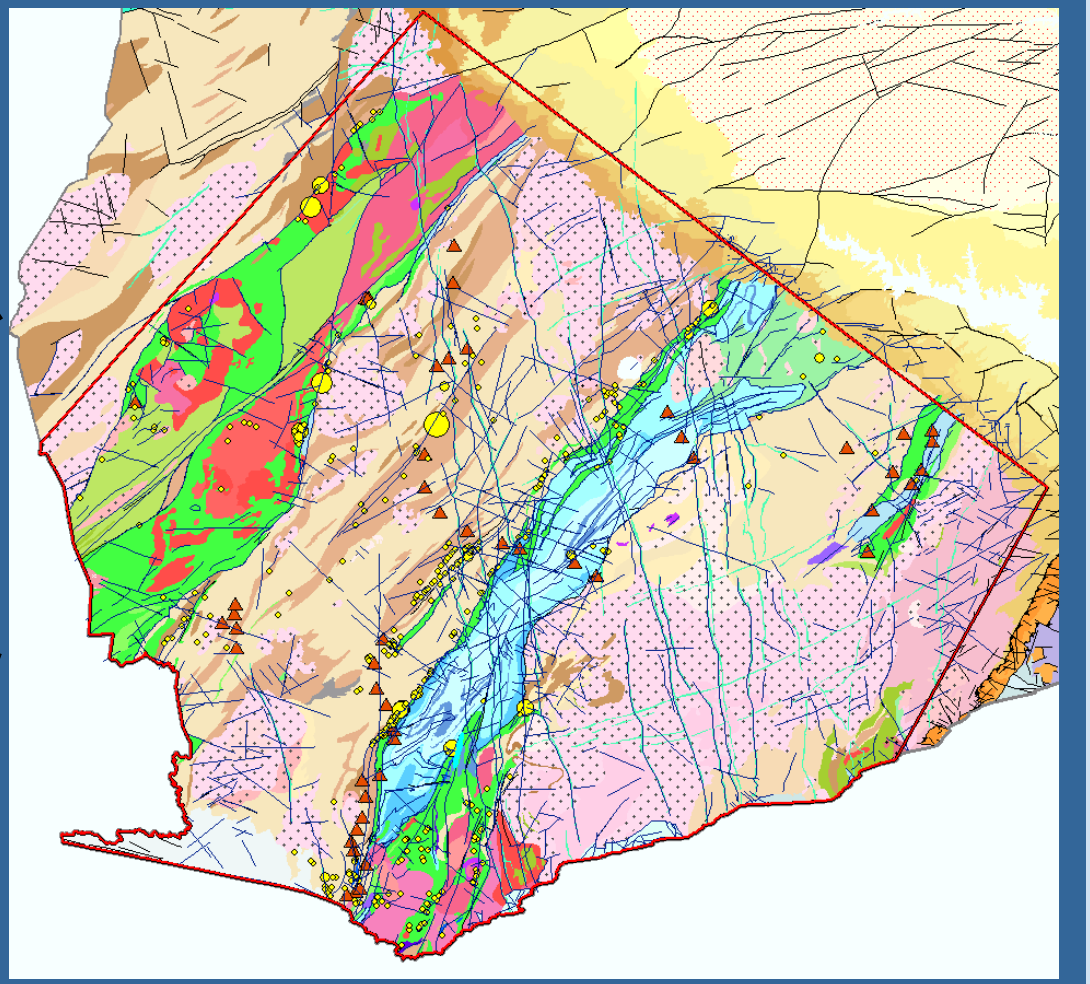
# Harmonizing Geological & Tectonic Data



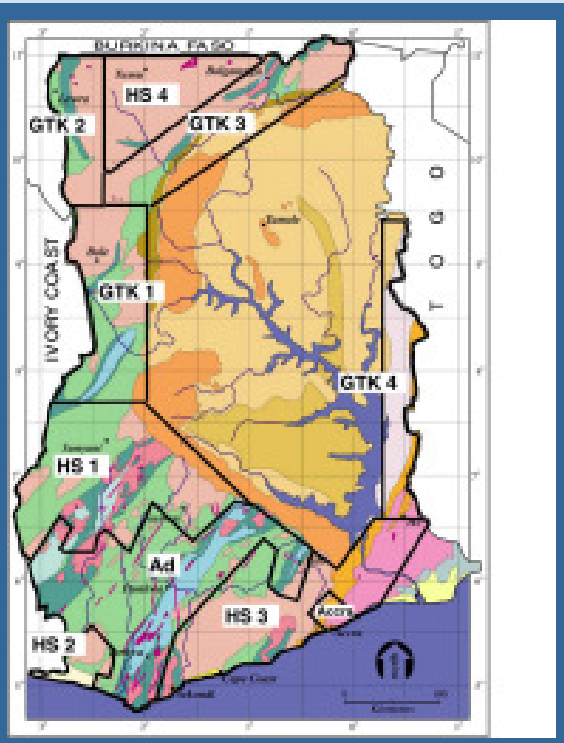

Minerals Commission, Griffis Consulting, 2002

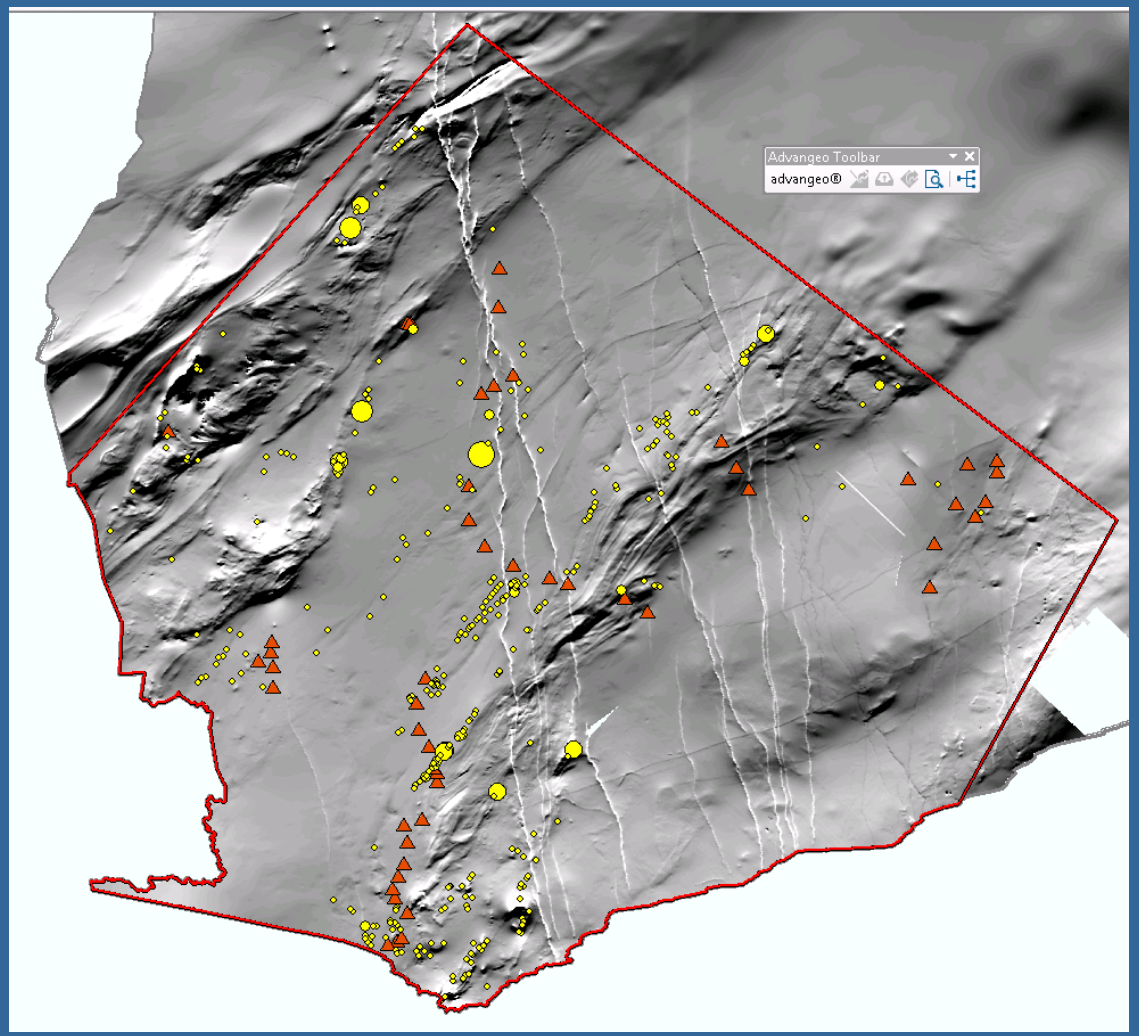


GSD, BGR, 2012



# Processing / Harmonizing Geophysical Data




**PROCESSING AND INTERPRETATION OF AIRBORNE GEOPHYSICAL DATA**

**AIRBORNE SURVEY 1999-2000**

Philip Yaw Oduro Amoako
Samuel Kwabla Amedofu
Thomas Akamaluk

Geological Survey Department of Ghana

February 2004

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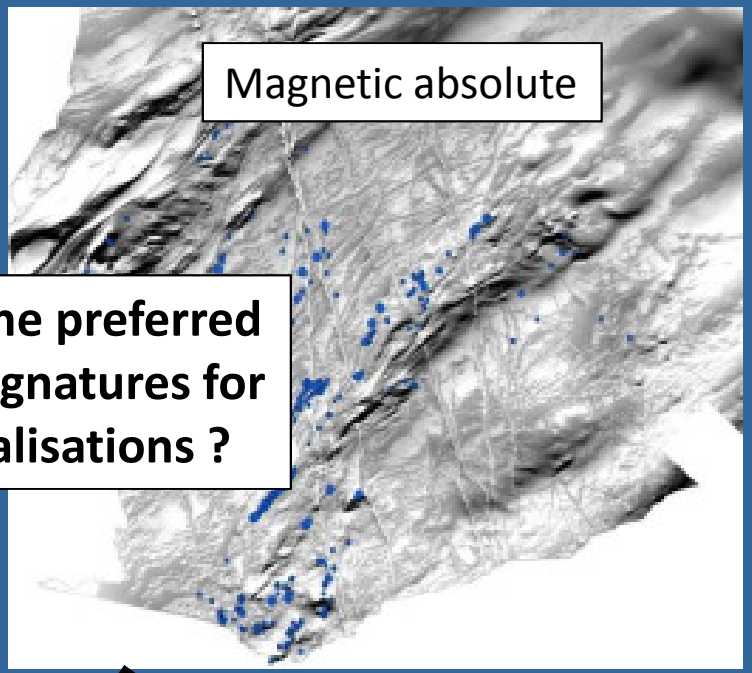
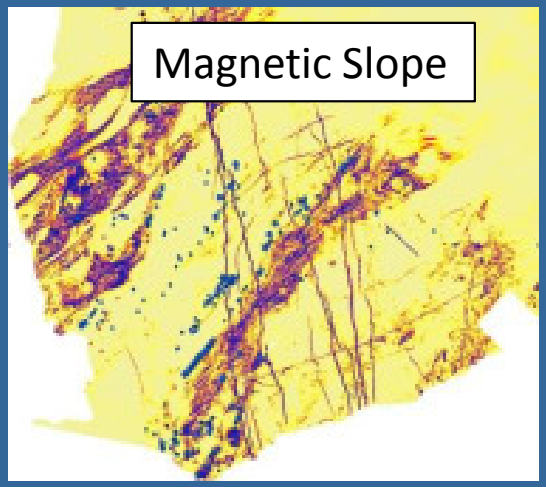
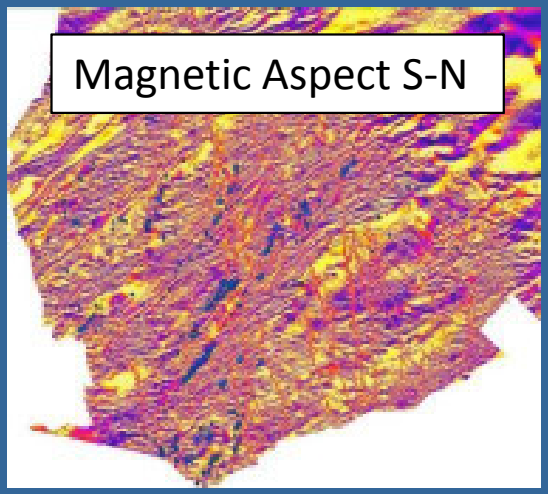
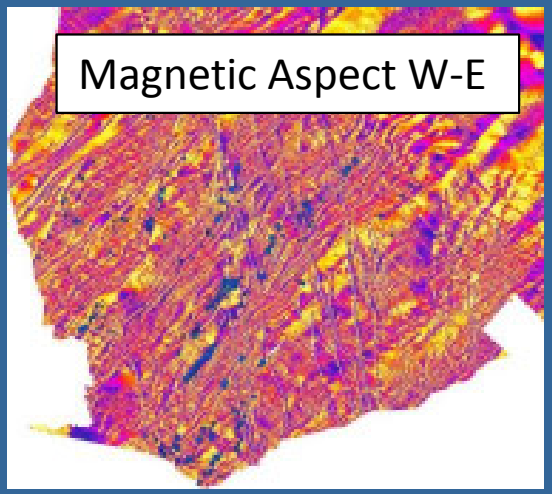
# Processing Magnetic Data: Derivatives

**What are the preferred magnetic signatures for Au mineralisations ?**



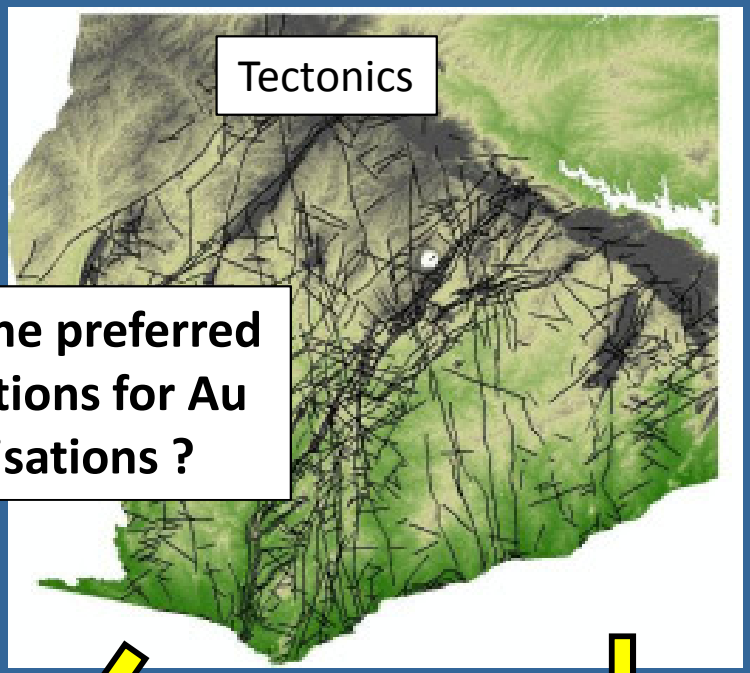



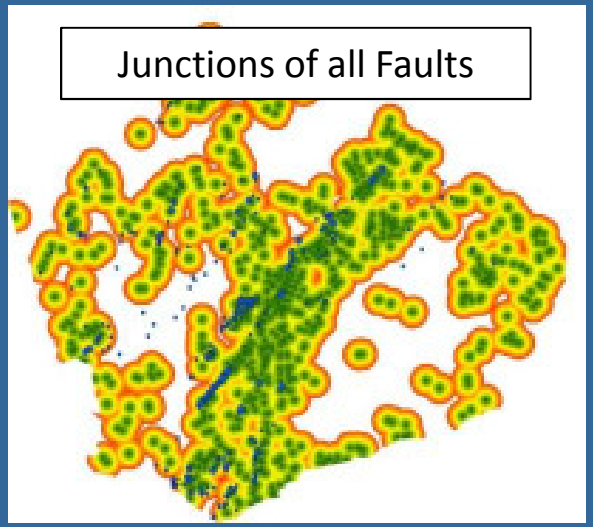



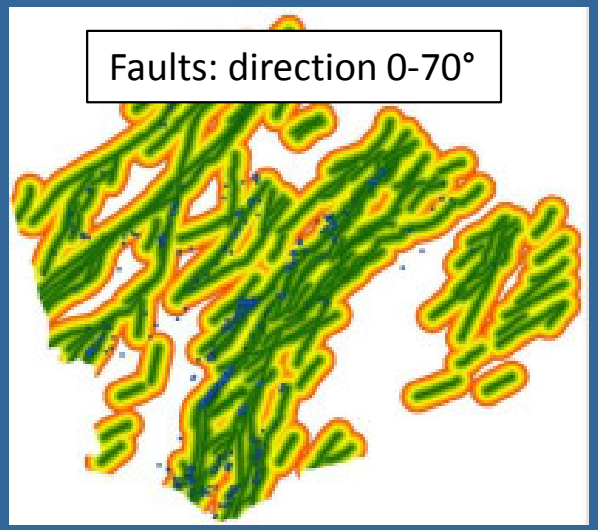



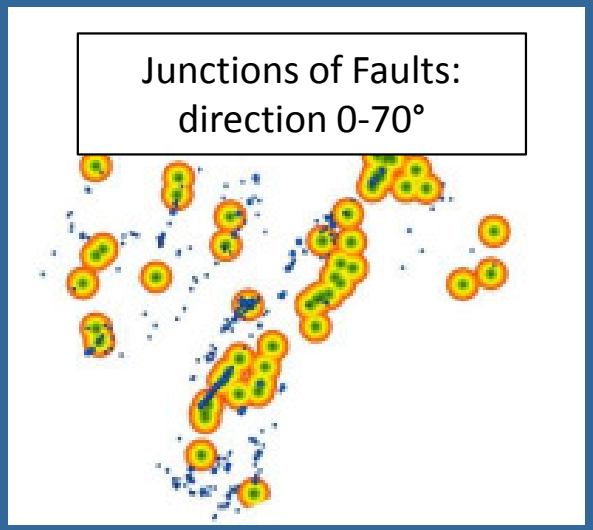
# **Processing Tectonic Data:** Direction / Intersections

**What are the preferred fault directions for Au mineralisations ?**



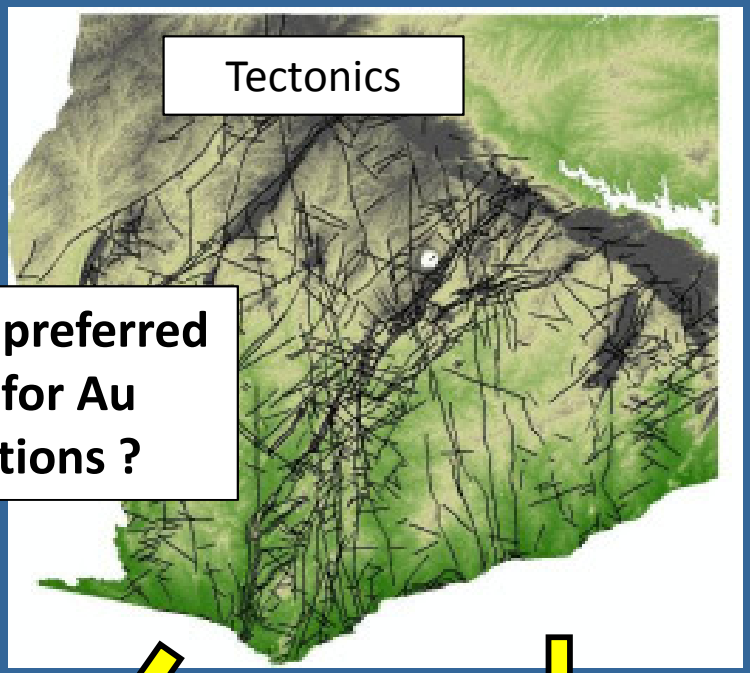



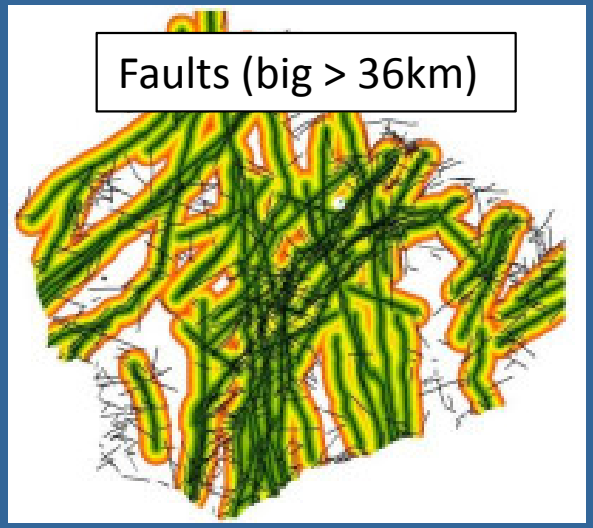



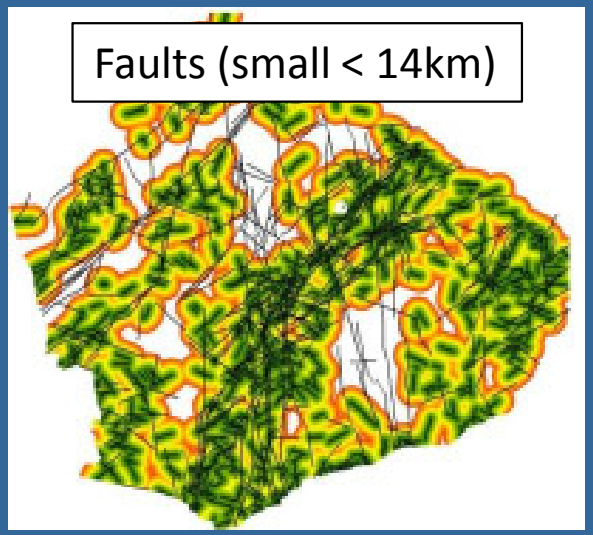



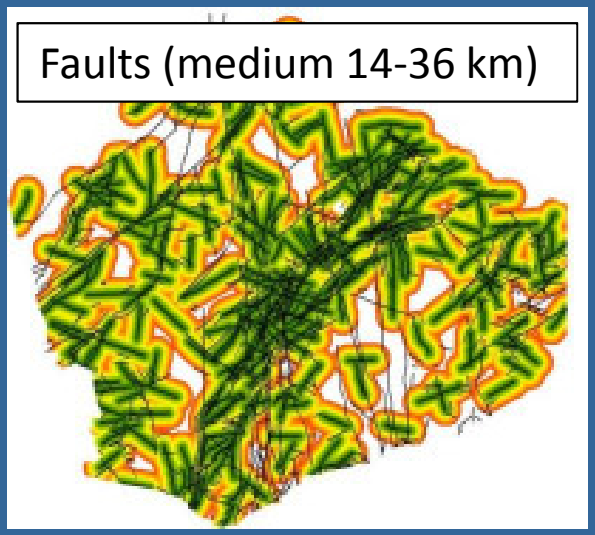
# Processing Tectonic Data: Size

**What are the preferred fault sizes for Au mineralisations ?**

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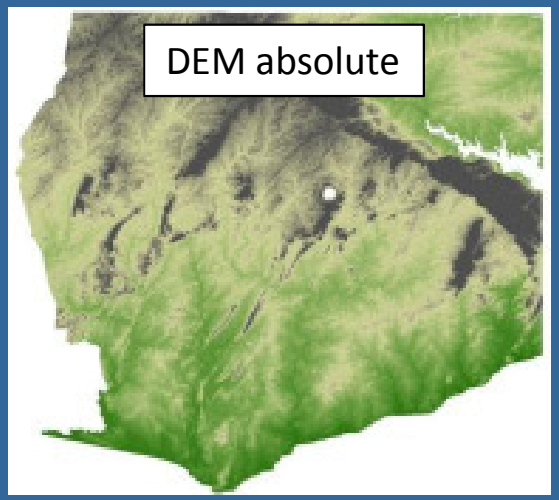
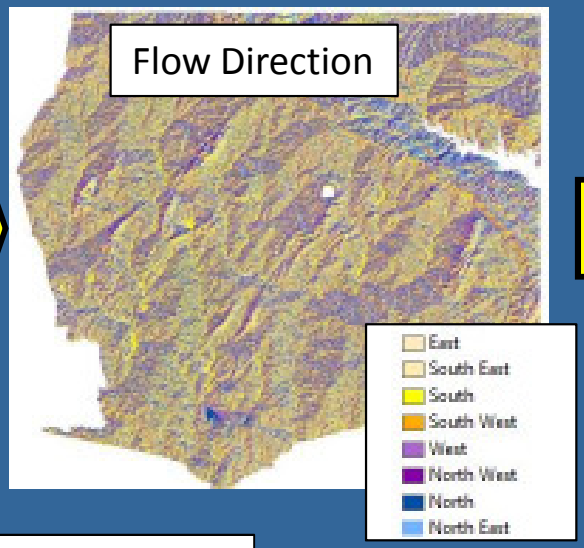
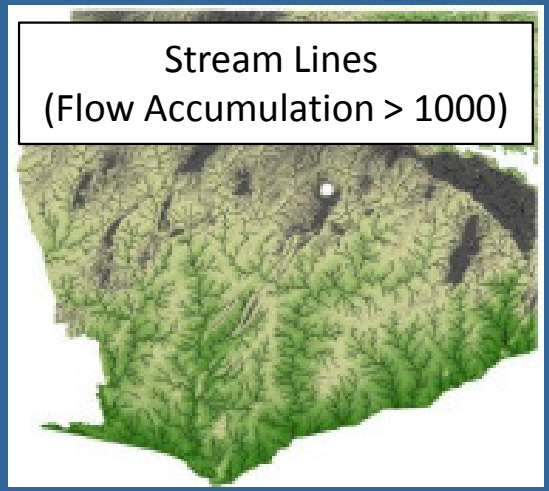
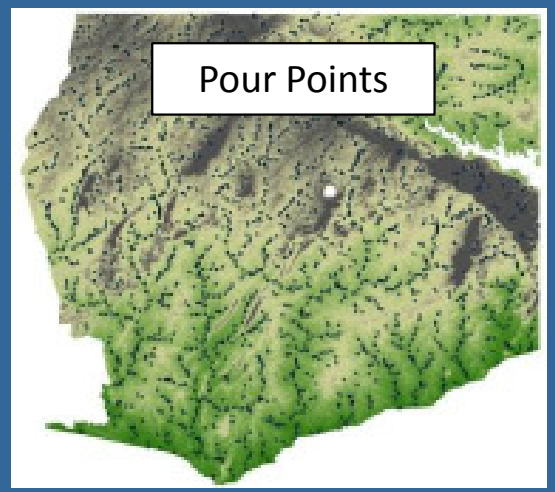
# Processing Elevation Model Data

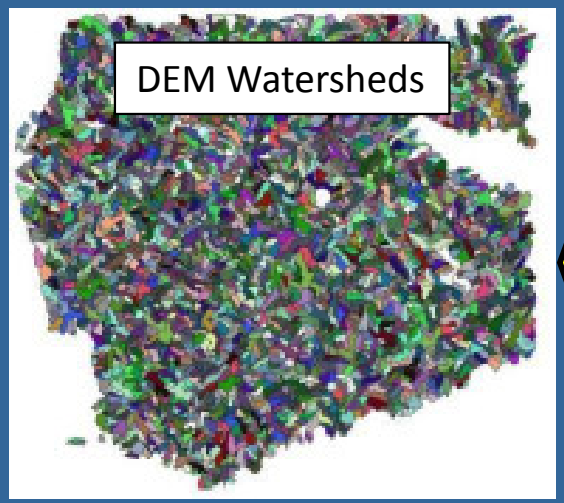


**What are the preferred catchment areas for Au mineralisations in placers?**

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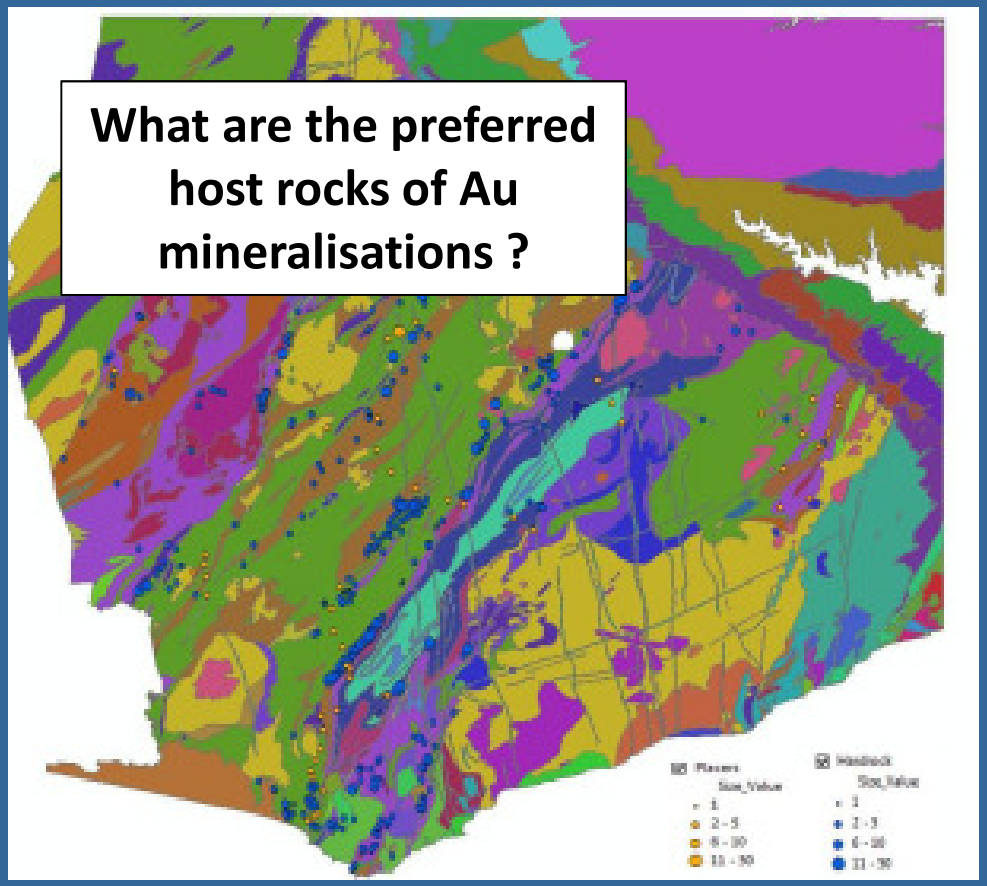
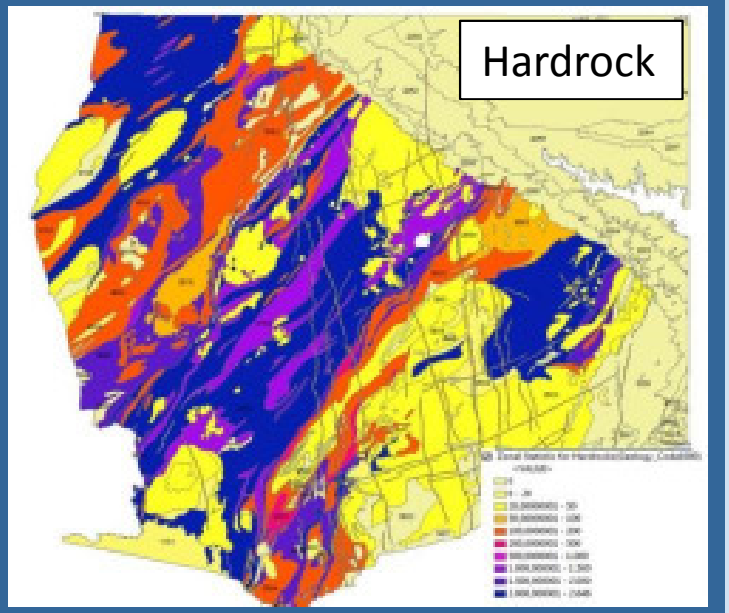
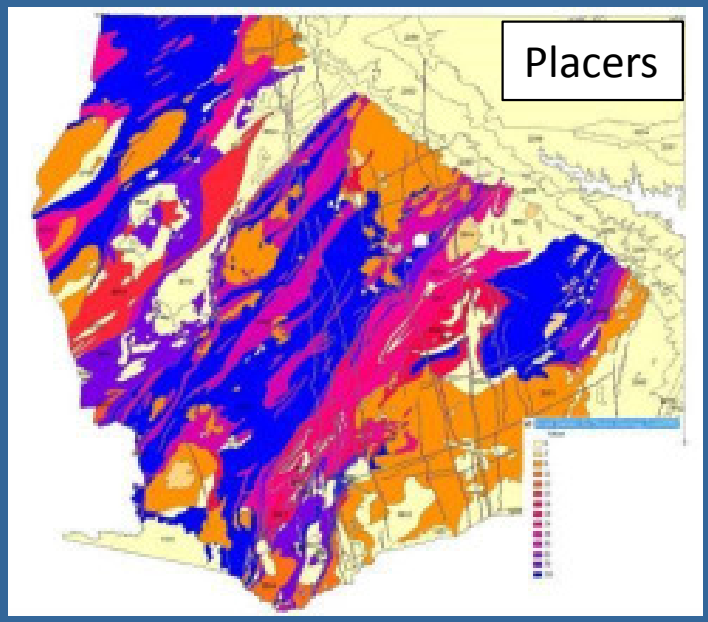
# Processing Geological Data



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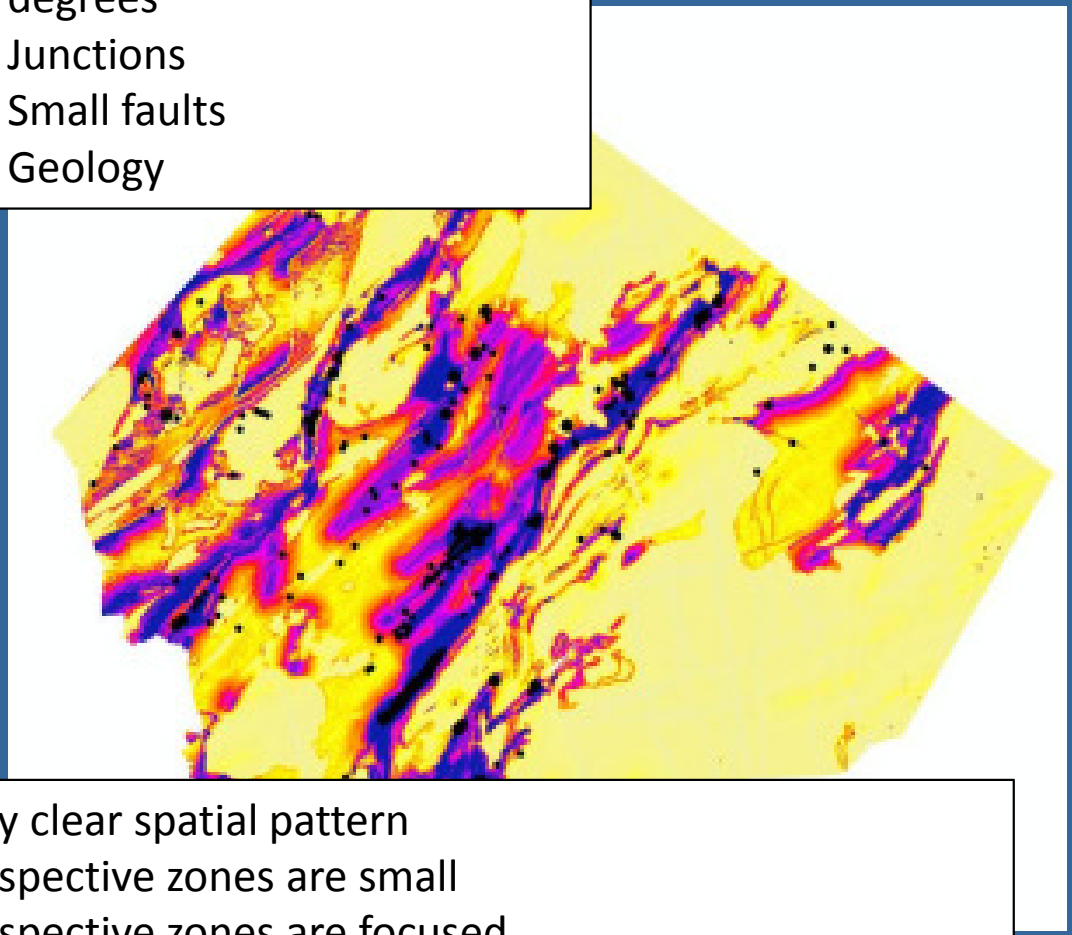
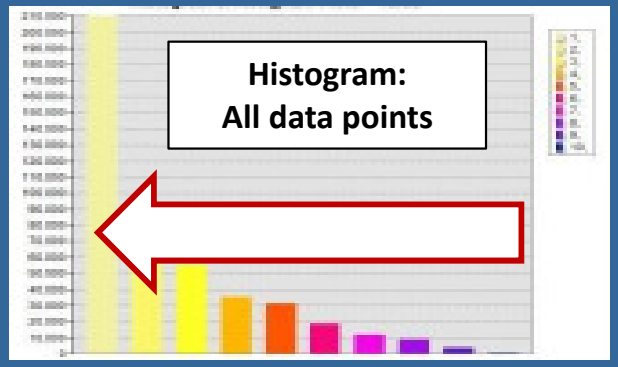
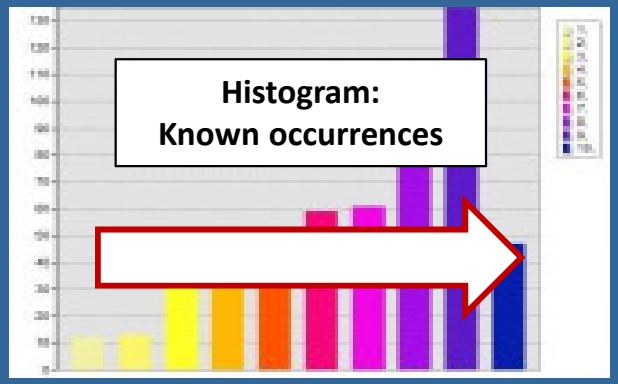
# **Qualitative Model:** Gold in Hard Rock

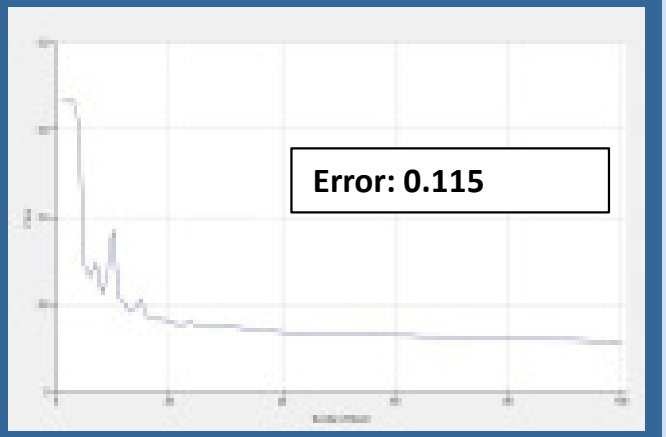
**Input Data:**

- Large faults
- Striking direction 5 – 75 degrees
- Junctions
- Small faults
- Geology






- Very clear spatial pattern
- Prospective zones are small
- Prospective zones are focused
- Most of known occurrences are located in high potential areas
- Low error: approx. 0.115

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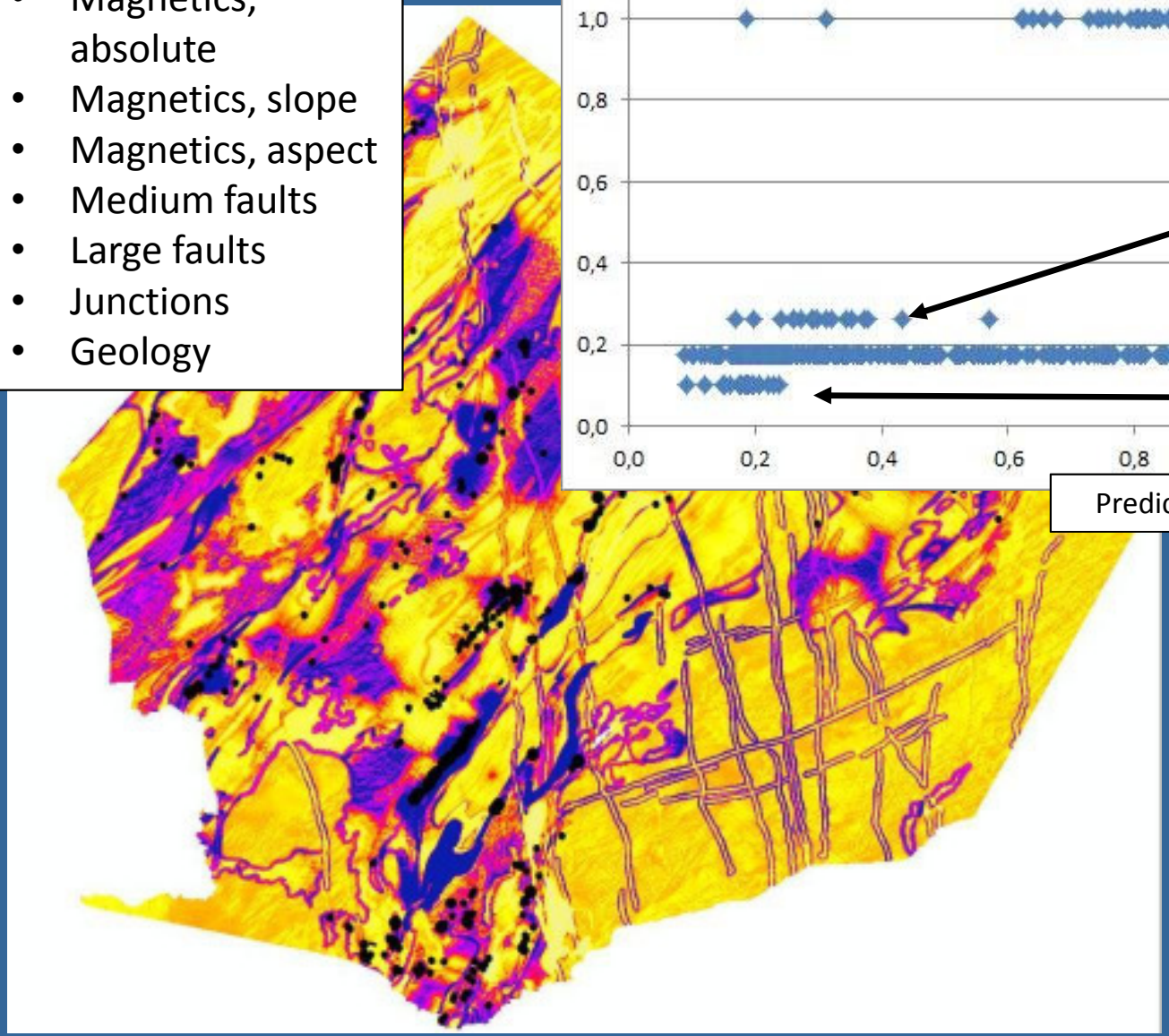
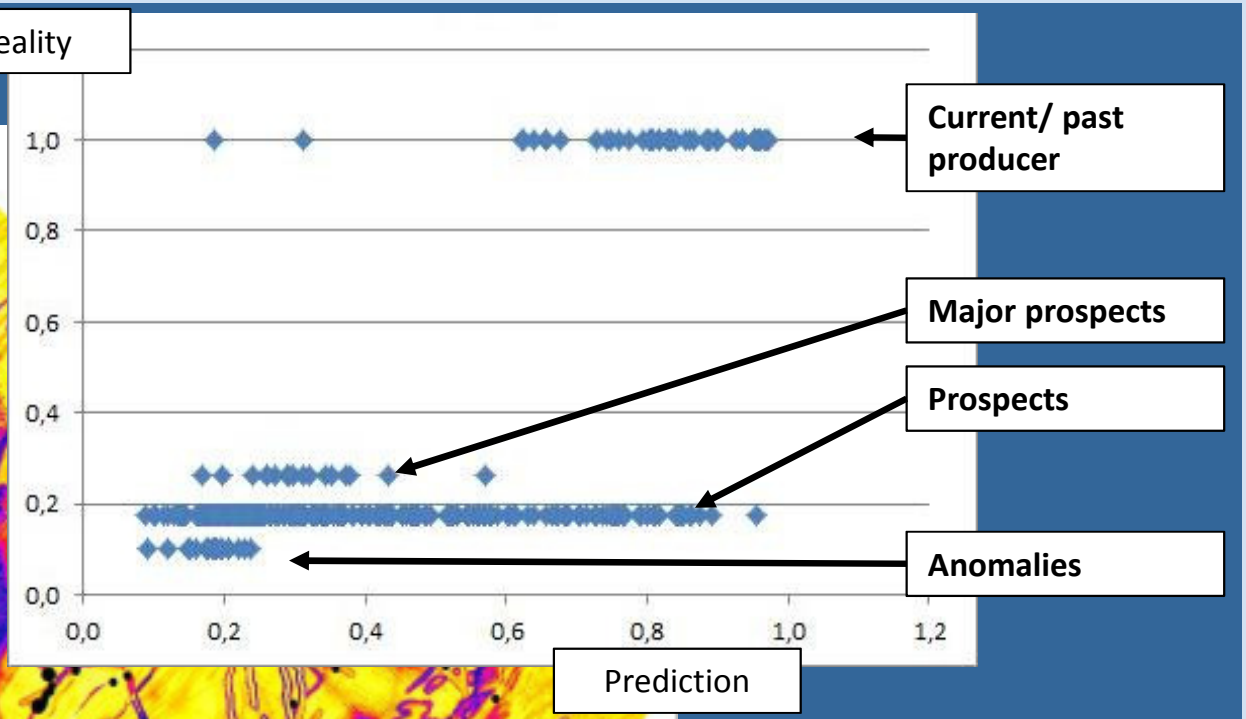
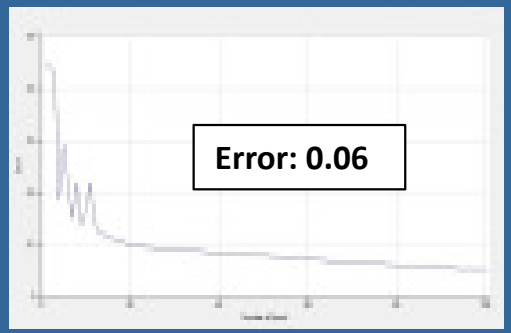
# **Quantitative Model:** Gold in Hard Rock

**Input Data:**

- Magnetics, absolute
- Magnetics, slope
- Magnetics, aspect
- Medium faults
- Large faults
- Junctions
- Geology

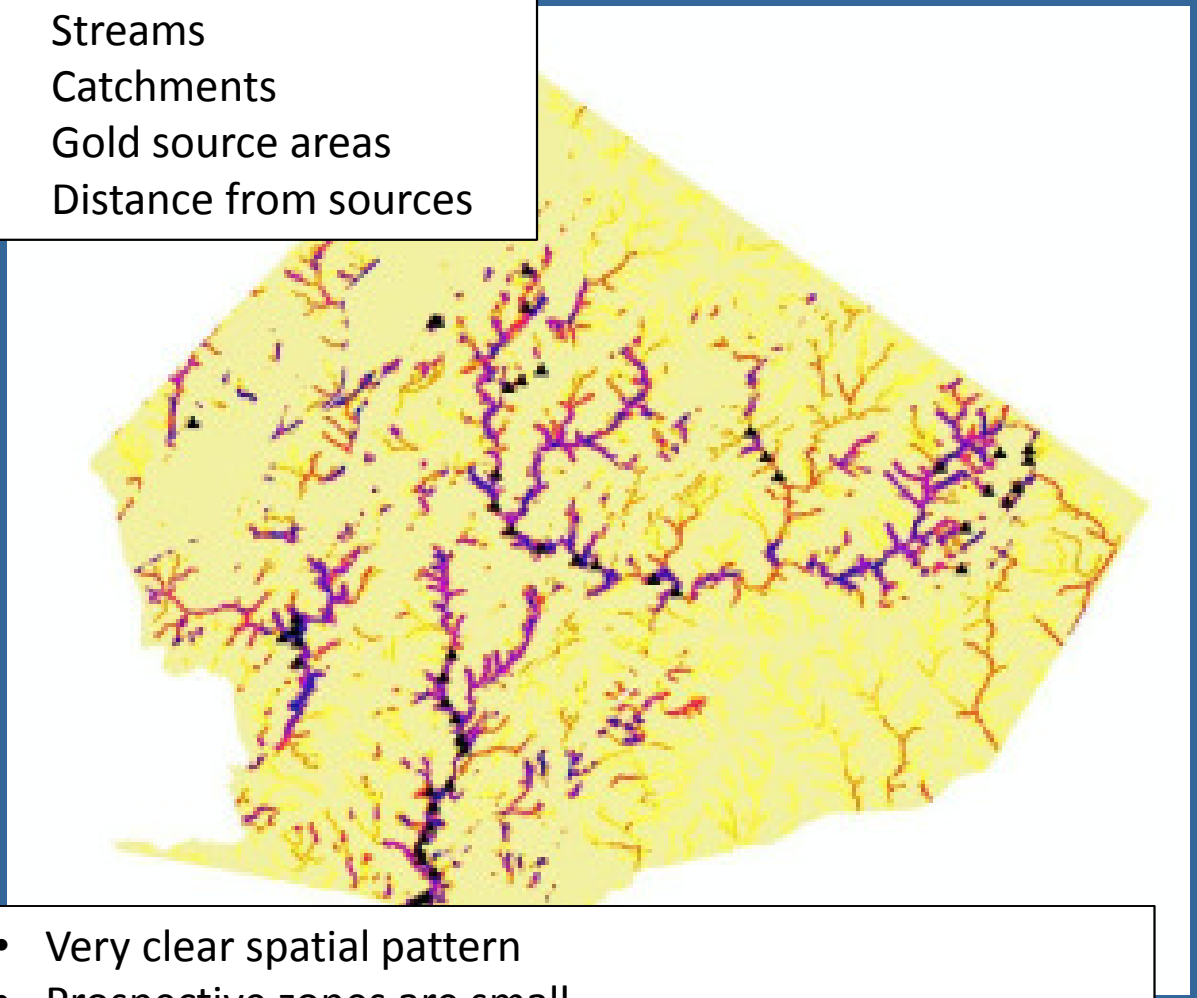


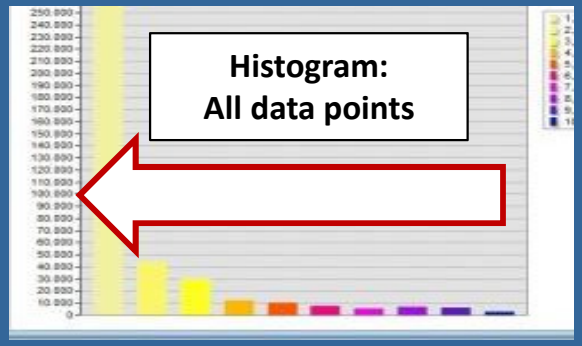


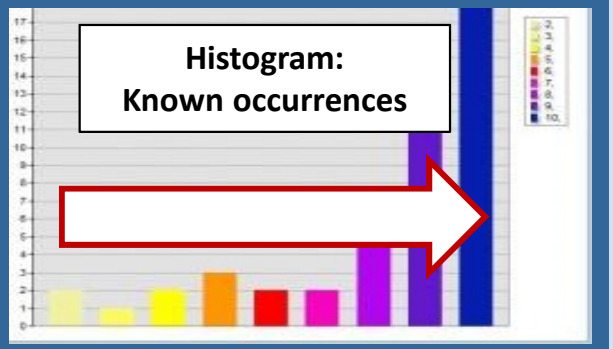



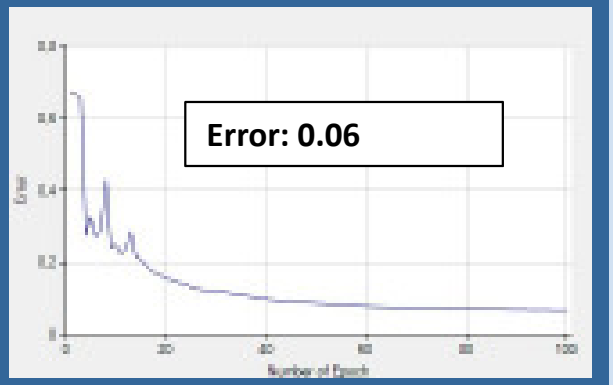
# **Qualitative Model:** Gold in Placers

**Input Data:**
- Streams
- Catchments
- Gold source areas
- Distance from sources






- Very clear spatial pattern
- Prospective zones are small
- Prospective zones are focused
- Most of known occurrences are located in high potential areas
- Low error: approx. 0.06

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# How to Build a Predictive Model?

❶ Definition of Model Accuracy / Resolution and Extent

❷ Selection and Harmonization of Source Data

❸ Processing of Source Data

❹ Preparation of Model Input Data

❺ Setting Up and Running of Different Model Scenario

❻ Presentation of Final Model Scenario Results

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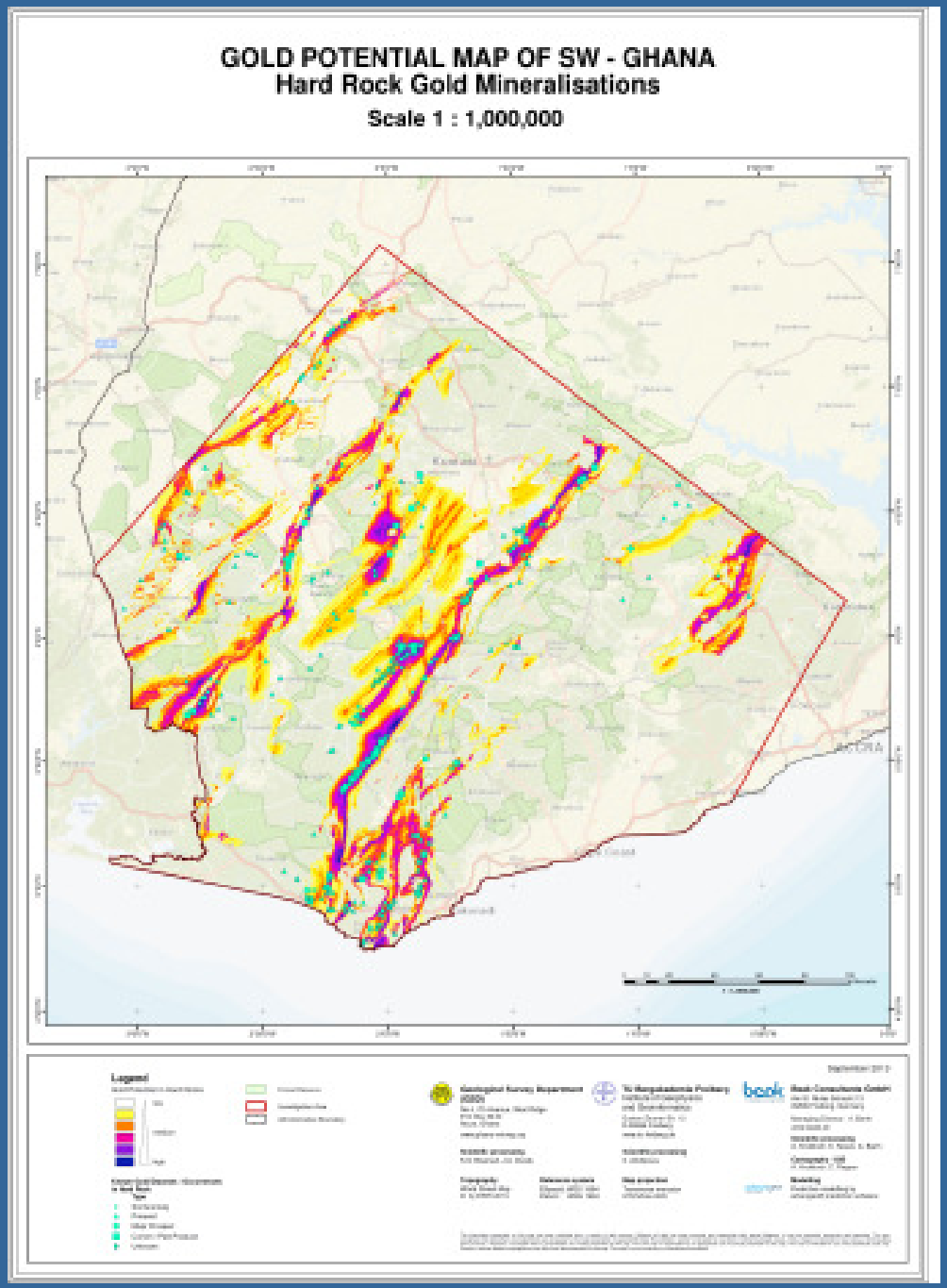
# Map Product and Application




**<u>Mineral Potential Map:</u>**
**Gold in Hard Rocks**

- Easy to read
- Sufficient accurate
- Represents existing knowledge
- Upgradable
- Usable for national/ regional planning activities
- Base for governance maps to:
  - Protect resources
  - **Guide big investment**
  - Analyze conflicts
  - Plan long term land use

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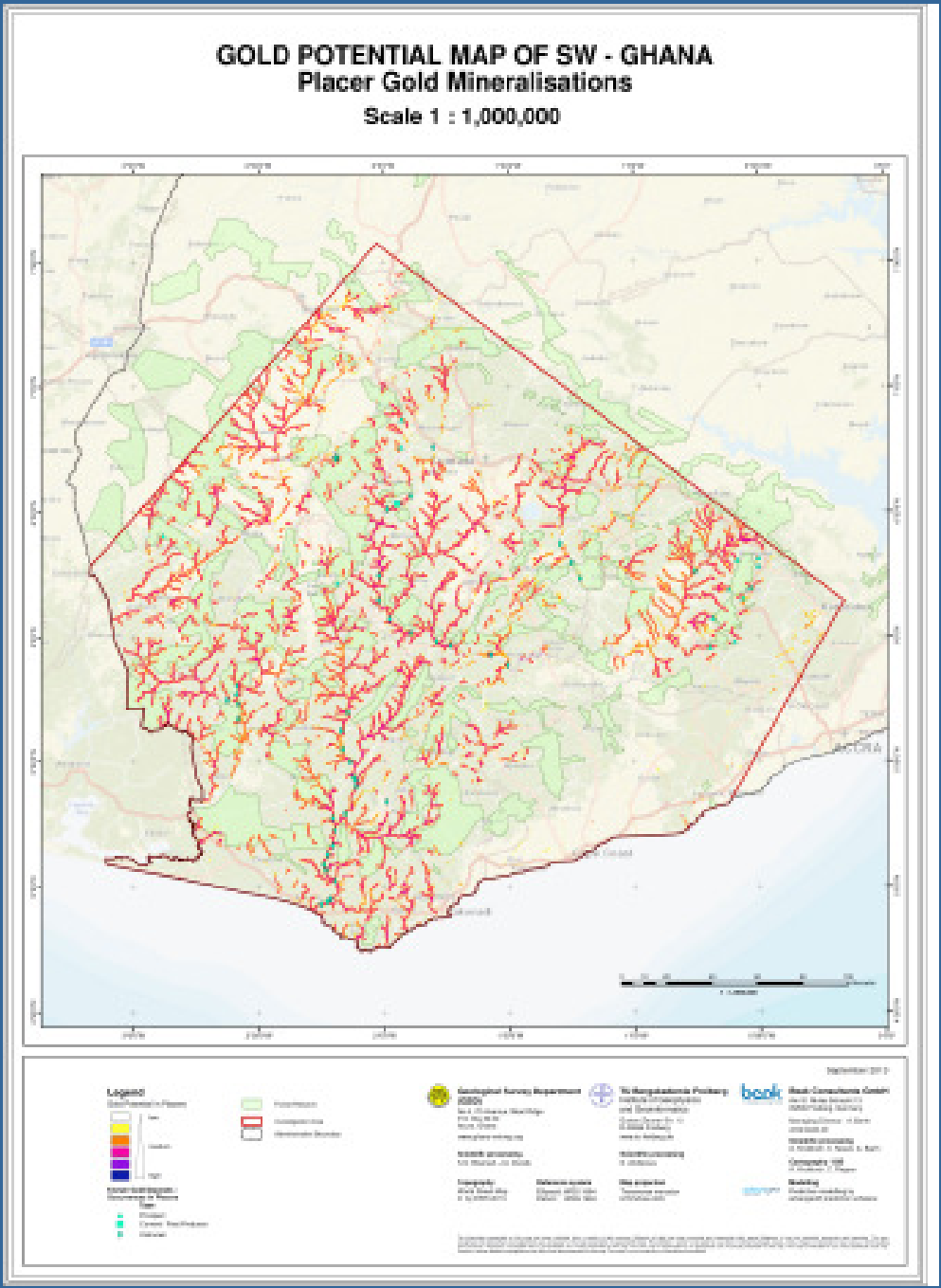
# Map Product and Application




**<u>Mineral Potential Map:</u>**
**Gold in Placers**

- Easy to read
- Sufficient accurate
- Represents existing knowledge
- Upgradable
- Usable for national/ regional planning activities
- Base for governance maps to:
  - Protect resources
  - **Guide small scale mining**
  - Analyze conflicts
  - Plan long term land use

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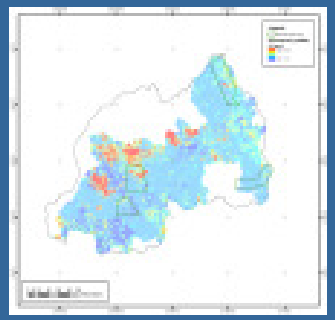
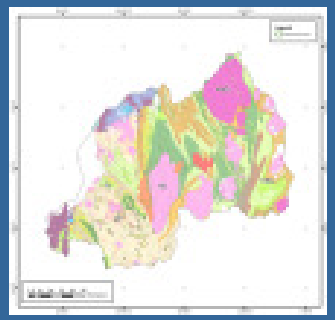
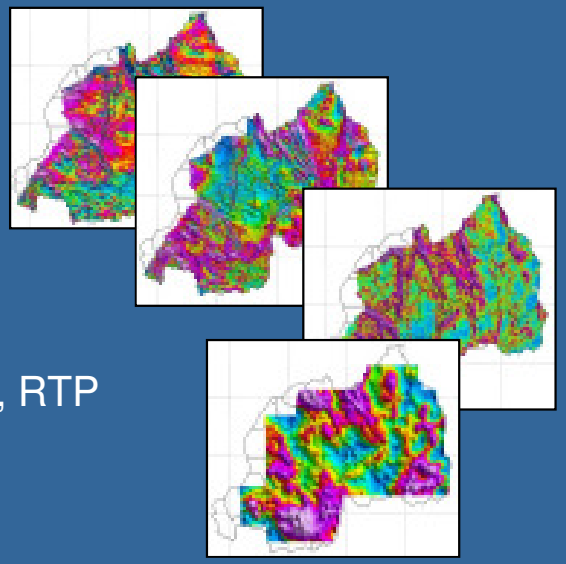
# CASE STUDY 2: Niobium-Tantalum / Gold in Rwanda

*Nb-Ta-Mineralisation in Pegmatites, Mwacka/ Rwanda*

*Au-Mineralisation in Quartz-Veins, Miyove/ Rwanda*

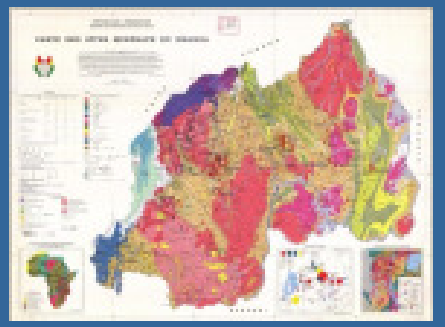
# Set-up of Predictive Model

**Input Data:**
Airborne Geophysics (PGW):
- Magnetic: Analytical Signal, TMI, RTP
- Radiometric: K, T, U, Total
- Gravimetric: Bouguer

Geochemistry (UNDP):
– Cu, Co, Ni, Pb, Sn, W, U, Zn

Geology:
– Distance to Faults



**Training Data:**
Known Mineralisations:
- Minerals Map
- Aerial Images

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Prediction Software

**Prediction Maps for Nb-Ta-Sn- & Au- Mineralisations**

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# How Can Mineral Predictive Maps be Used ?

- **Protect resources !!!**
  - No further blocking by roads, settlements, water dams, ...
  - Keep resources available for the future
- **Guide exploration activities**
  - Support exploration targeting
  - Support small scale mining
- **Integrate mining into social and economic development**

→ **Minimize conflicts with:**

- Infrastructure
- Agriculture
- Nature conservation

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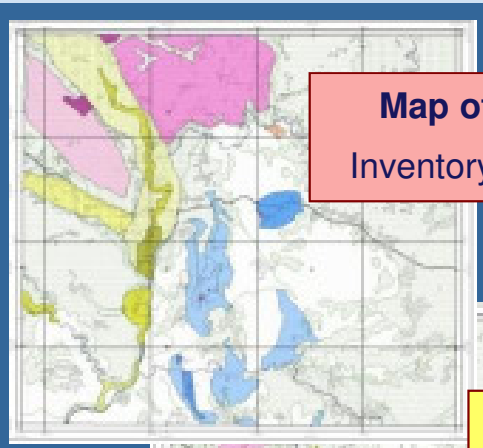
# Land Use Conflict Analysis

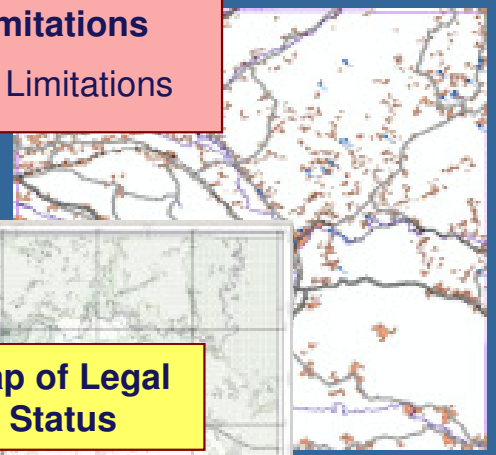


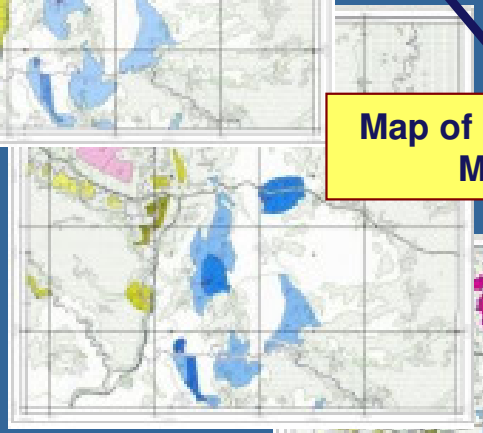
**Map of Minerals**

Inventory of Minerals

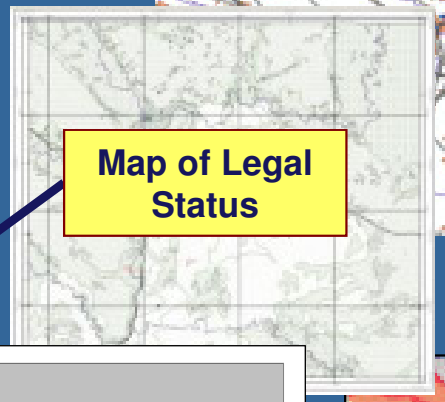
**Map of Limitations**

Inventory of Limitations

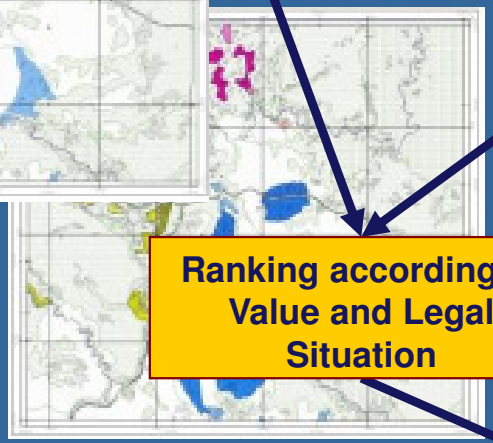




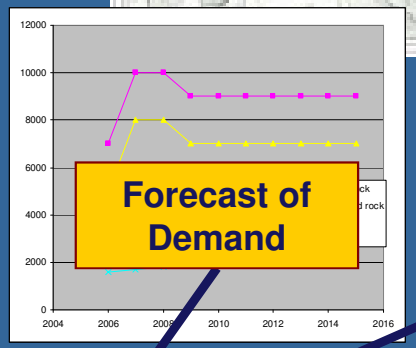
**Map of Non-Blocked Minerals**



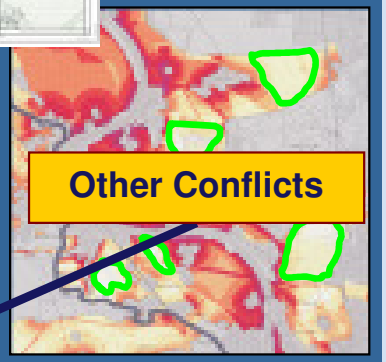
**Map of Legal Status**



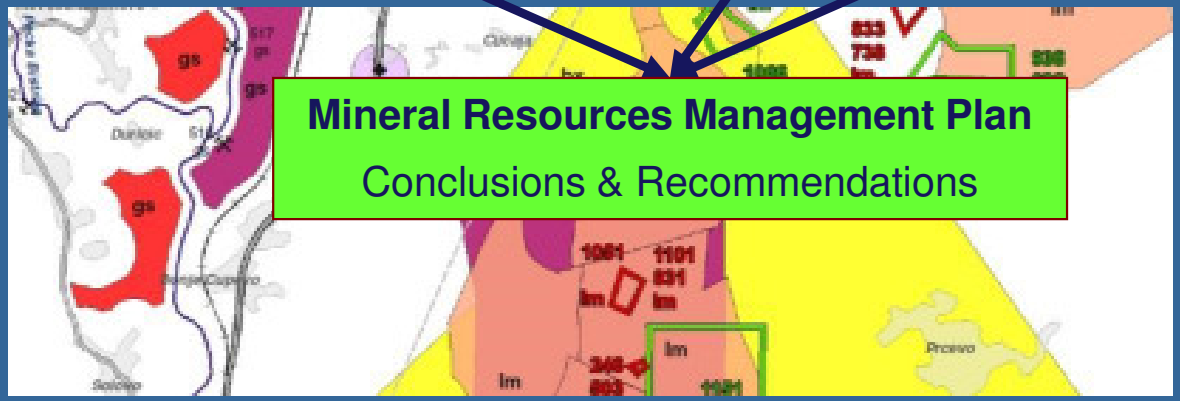
**Ranking according to Value and Legal Situation**




**Forecast of Demand**



**Other Conflicts**



**Mineral Resources Management Plan**

Conclusions & Recommendations

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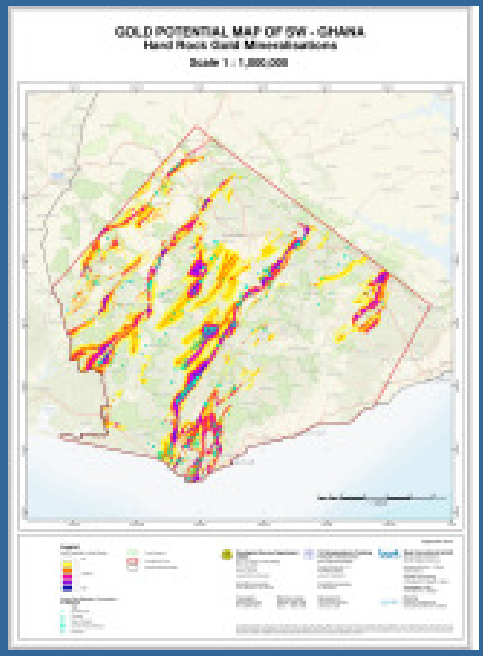
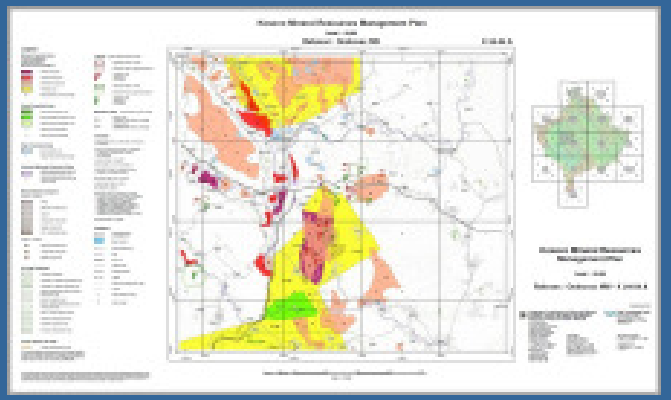
# Conclusions

- **Mineral predictive maps <u>support</u>:**
  - Informed decision making
  - Investment attraction
  - Small scale mining




- **Mineral predictive maps <u>save</u>:**
  - Exploration funds
  - Use of land

- **Mineral predictive maps <u>help</u>:**
  - Create mineral resource management plans
  - Develop infrastructure



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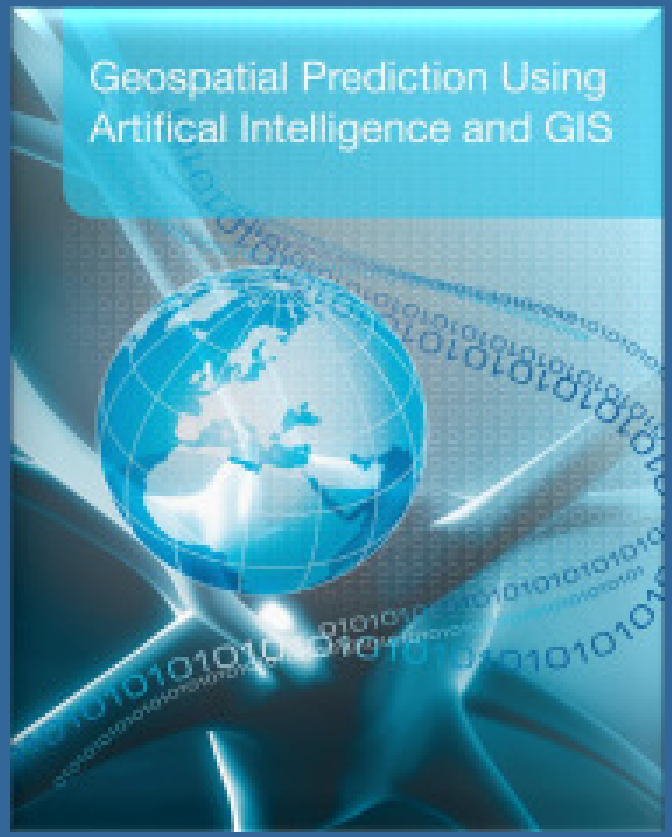

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andreas.knobloch@beak.de