UNITED NATIONS UNIVERSITY
UNU-GTP
Geothermal Training Programme

SUSTAINABLE DEVELOPMENT GOALS

INTRODUCTION TO GEOLOGICAL MAPPING

Risper Kandie

Geologist-KenGen

Email: rkandie@kengen.co.ke

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Sustainable Development Goals Short Course IV
on Exploration and Development of Geothermal Resources

UNU-GTP

KenGen

Contents

Introduction

Approaches

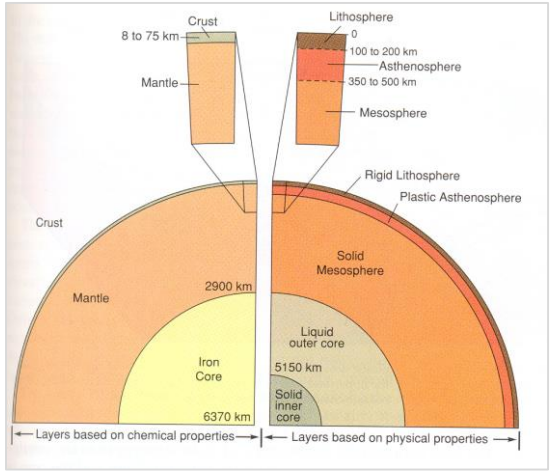
Exploration stages

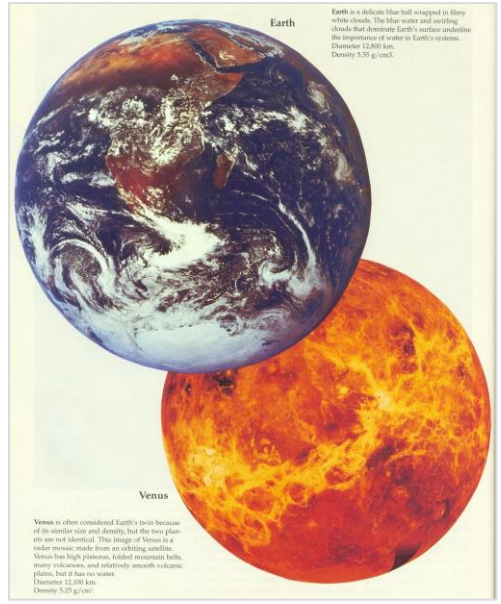
Requirements: Fieldwork data acquisition and report

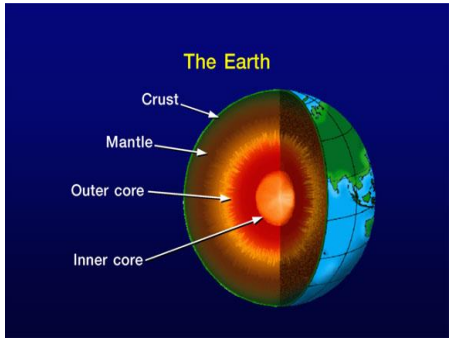
WHAT IS GEOLOGY

Earth science discipline concerned with study of earth

- Composition & Structure







- Chemical & Physical forces

BASICS OF GEOLOGY

❖ Branches: Pure &Applied geology:

❖ Areas of specialization in pure Geology include:

-*Mineralogy*-(Minerals)

-*Petrology-* (Rocks)

-*Historical Geology-* (Paleontology, Stratigraphy, Paleo-climatology)

-*Physical Geology-* (Geomorphology) earth's surface features & their origin.

-*Geochemistry*-Composition of the earth by applying the principles of Chemistry

-*Geophysics-* Earth's internal structure and processes by using the principles of physics.

-*Structural & Tectonics-* Structural features of the earth and the effects of internal processes on earth's surfaces, oceanography and orogenesis

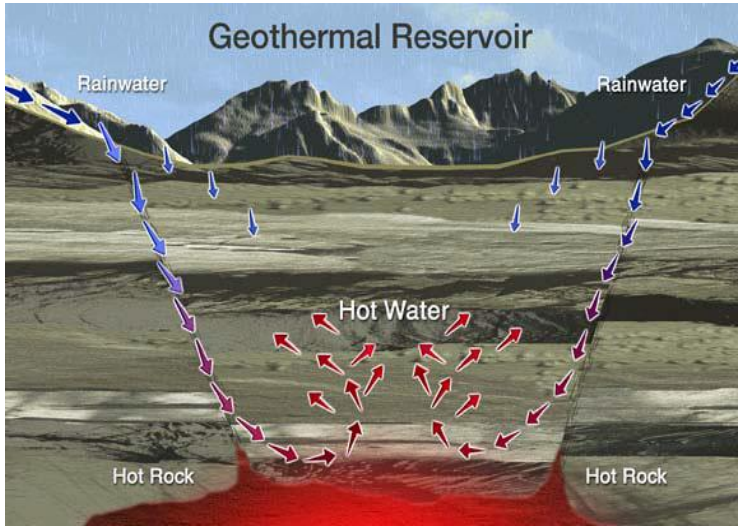
GEOLOGICAL MAPPING

Definition: Geologist making physical observation and recording

Geologist's role

- Apply geology to understand the geological settings with respect to tectonics
- Investigate geological phenomena and establish their relationship to existence of geothermal resources
- Develop an understanding of existence of geothermal system;
  - ❑ Heat
  - ❑ Permeability-pathways
  - ❑ Fluids /water
  - ❑ Reservoir and cap rocks
  - ❑ Recharge

- Map to prioritize the most promising targets



APPROACH

- **Project proposal**
  - ➢ Strategy to deal with objectives
  - ➢ Understandable problem definitions
    - ❑ multiple working hypotheses
  - ➢ Methodologies to be employed
  - ➢ Clear outcome of the exploration program
  - ➢ Area of study and life span of the project.

EXPLORATION STAGES

1. Pre-field Work

   ✓Desktop studies

2. Orientation Survey

   ✓Reconnaissance

3. Preliminary/Detailed Exploration

4. Post Field Work

   ✓Lab analysis and report writing-conceptual model

1. PRE-FIELD WORK

Desktop studies and literature review;

- ✓Evaluation of all available information/previous work data/reports/conceptual model

- ✓Interpretation of satellite images, Remote Sensing and GIS data

  - ❑lithology and structural Information

2. ORIENTATION SURVEY

Verification and selection of most ideal exploration potential target area for consideration

(a) Site visits

Geomorphology of project area (flat, rugged, drainage pattern and accessibility and favorability for traverse,

- ✓ Distance area of interest and accessibility (road, trail, train, plane)
- ✓ Geologic conditions like availability of outcrops, thickness of soil cover, rock distribution and structural setting etc.
- ✓ Availability of resources such as water, telephone, electricity, manpower.
- ✓ Update or design work activity plan
- ✓ Assess working environment, season of the year etc.
- ✓ Validate (confirm) whether the target area is appropriate to conduct detail exploration or not.

b) Seek approvals

c) Inception report

3. PRELIMINARY/DETAILED SURVEY

Geological surface investigations

(1) Mapping surface geology and collect data on;

i. lithology and stratigraphy; potential reservoir/caprocks

ii. description of geological history

(2) Mapping of volcanic eruption features

i. Identify volcanic feature/eruption centres; of recent geological age, which indicate the presence of hot magma chambers close to the surface.

ii.their nature and type of formation

iii.Document eruption episode

(3) Mapping of geological structures; fault, fracture zones

i. Active-young-relation permeability

ii. Types, location, nature and orientation, sense of movement

(4) Mapping of thermal anomalies/ hydrothermal alterations

i. Thermal manifestations; steam vents, geysers, hot springs, hot ground, boiling mud etc.,

ii. Types, location, nature-active /extinct

iii. Hydrothermal alterations provides clues to cap rocks

REQUIREMENTS

- Personnel
- Tools & equipment
  - ✓ Sampling and recording
- Logistics
- Accommodation and other basic needs
- Basic skills-First Aid, swimming, driving, riding
- Physical fitness

TOOLS AND EQUIPMENT

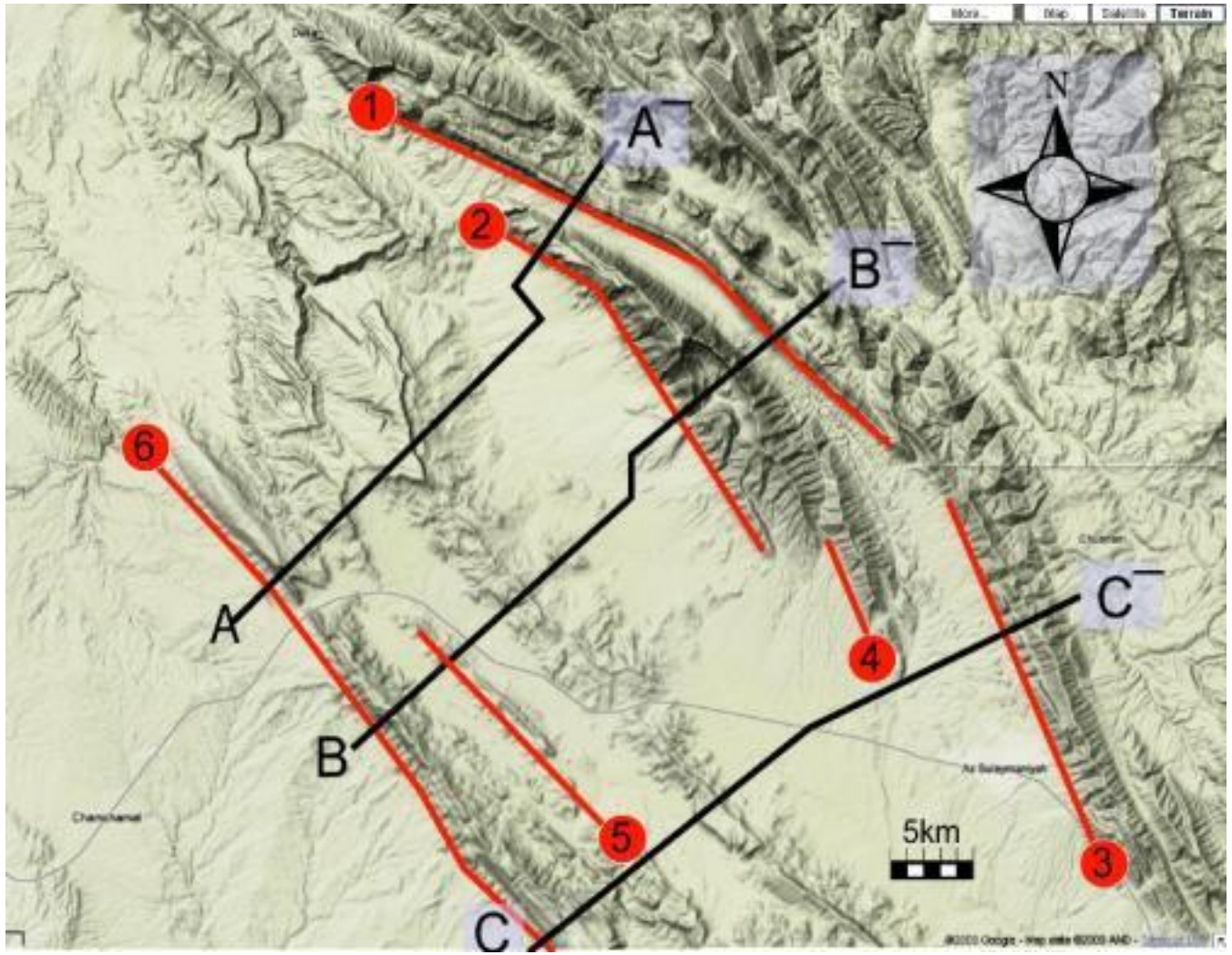
- Maps of appropriate scale; Topographic base maps
- Aerial, Images-sat, lidar
- Geological hammer
- GPS
- Stereoscopes
- Clinometers and compass
- Camera
- Binocular
- Stationeries-notebook, pencils, marker pens
- Vehicle

- Thermocouple
- Portable X-ray Fluorescence
- Tape measure
- Hand lens
- Sample bags
- PPE-shoes, rain gear, hat, goggles, gloves
- Others:, F/Aid kit, Anti-snake bite, HCL
- Rucksack
- Geologist imagination

MAPPING TECHNIQUES

(a) Traverses

- ❑ Cross-section traverses
- ❑ Stream traverses
- ❑ Road traverses



MAPPING TECHNIQUE CONT'D

(b) Boundary mapping or following Contacts

- Trace contacts between rock formations, groups and types
- Rock formation exposures

(c) Exposure

DATA COLLECTION

(i) Geological

(ii) Structural

(iii) Alteration and thermal manifestations

(iv) Volcanology

(I) GEOLOGICAL DATA

Rock samples

- ✓ Note location
- ✓ Obtain in situ sample
- ✓ Description
- ✓ Establish rock contacts and sequence
- ✓ Take dip and strike measurements on planar surfaces
- ✓ Labeling

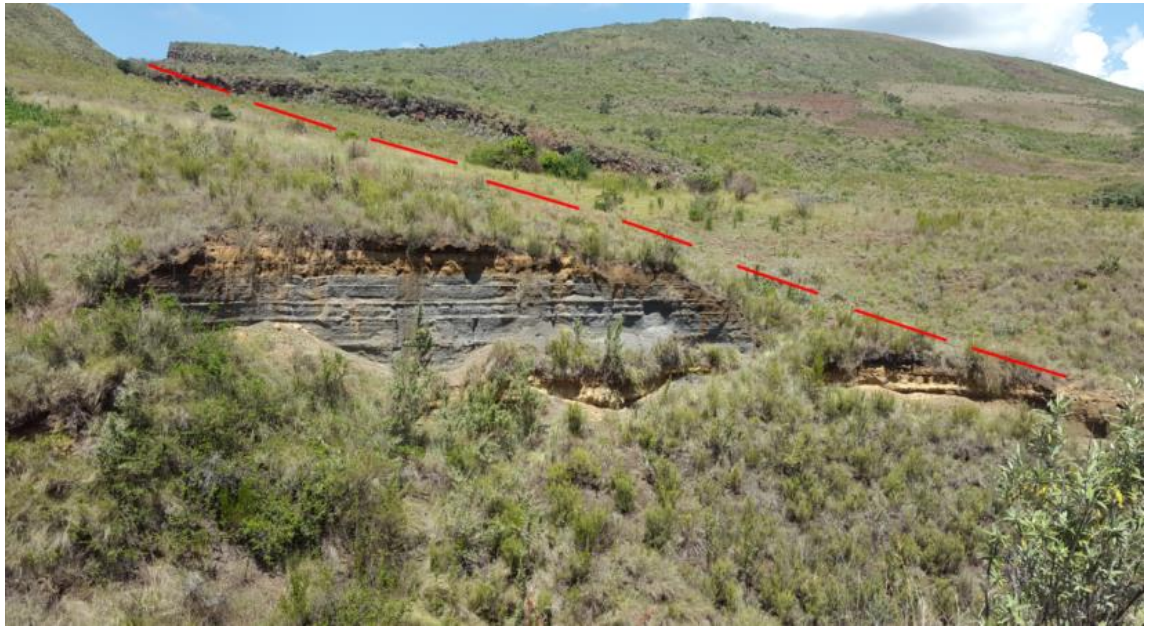
(2) STRUCTURAL DATA

(a) Faults

Existence of faults indicative features

(i) Structural features

- ✓Offset features (rocks & topographic)/displacement of planar structures
- ✓Slickensides and slickenslines
- ✓Gouge/breccia
- ✓ Mylonite
- ✓Shear zone
- ✓Juxtaposition of dissimilar rock types



(2) STRUCTURAL DATA CONT'D

(ii)Geomorphic features

- ✓fault scarp
- ✓fault-line scarps
- ✓increase of stream gradients at the fault line
- ✓hanging valleys
- ✓aligned springs and vegetation
- ✓Landslide features/hammock grounds
- ✓displaced stream courses
- ✓Geothermal manifestations alignment

(2) STRUCTURAL DATA CONT'D

(b) indicative features of Recent/ active faulting

- Fault scarps: vertically displaced ground surface resulting from dip-slip faulting (normal and reverse faults)

- Historic seismicity/recent seismicity

Data acquisition

✓ Track its extent and record using GPS
✓ Determine trend
✓ Estimate displacement & throw direction

(2) STRUCTURAL DATA CONT'D

(b) Joints &veins

Are a type of fracture which form due to tension

They form parallel to the minimum tensile stress

- Columnar Jointing
  - ✓Fractures formed in basaltic lava due cooling and shrinkage
  - ✓Polygonal columns
  - ✓Good facing indicator

- Measure the orientation and dimensions
- Establish open or closed/ mineralized

NB. Take photographs with scale and make sketches

VOLCANOLOGY DATA COLLECTION

(i) Eruption centres

- Type-crater/caldera volcano
- Extent, age, nature

(ii) Eruption materials

- Patterns, provenance, thickness, volume
- Note colour and mineral composition
- Samples for tephrachronology analysis and age dating

(iii) Intrusive

- Orientations, trends, type, nature, dimensions

(iv) Flow structures

- Pahoehoe; Ropy lava - Good flow direction indicator

NB. Volume, age, genesis of rocks

relates to magma body-heat source

(4) ALTERATION & THERMAL MANIFESTATIONS DATA

Parameters to be measured and recorded

(pH, temp, odour, colour, deposits, extent, flow rates, nature-active/extinct)

- Fumaroles –informs on permeability, reservoir temp.
- Geysers- vapour dominated, permeability
- Hot springs-liquid system, permeability
- Warm/steaming grounds-permeability
- Altered grounds –permeability, cap rocks
- Associated deposits
  - Silica sinter-
  - Travertine-
  - Sulphur –proximity at top of magma chamber

POST FIELD WORK

Laboratory works:

(i) Rock samples

- ✓ Thin and polished sections
- ✓ Analysis in petrographic microscope

(ii) Alteration samples

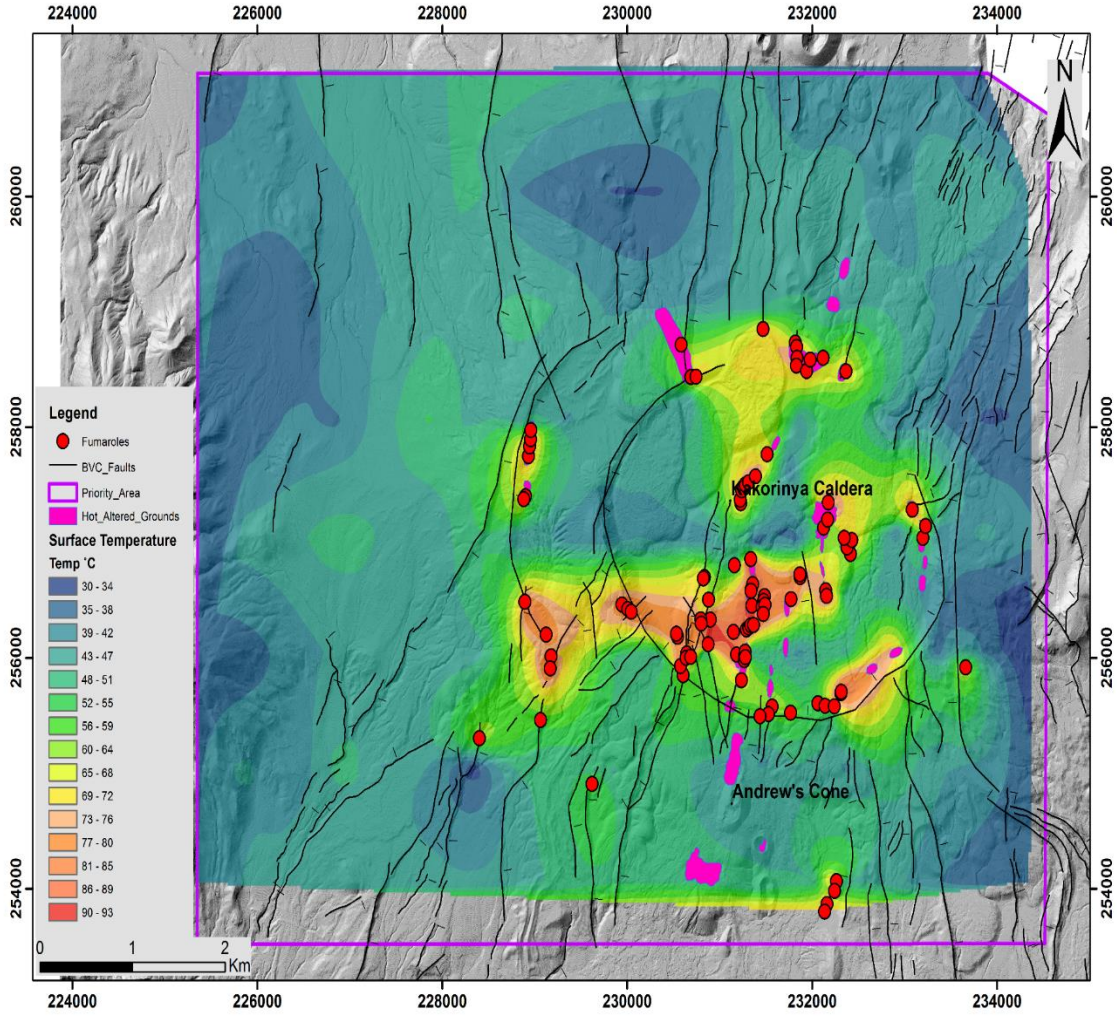
- ✓ Sample preparation for XRD analysis
- ✓ Analysis and interpretation

(iii) Structural data

- ✓ Analysis of strikes and dips with use of use of
  - ✓ e.g. Rose diagram
- ✓ Export the GPS data to appropriate software
- ✓ Interpret and determine tectonic regimes
- ✓ Generate structural map

(iv) Geothermal manifestation data

- ✓ Tabulate, interpret and generate isomaps



REPORT

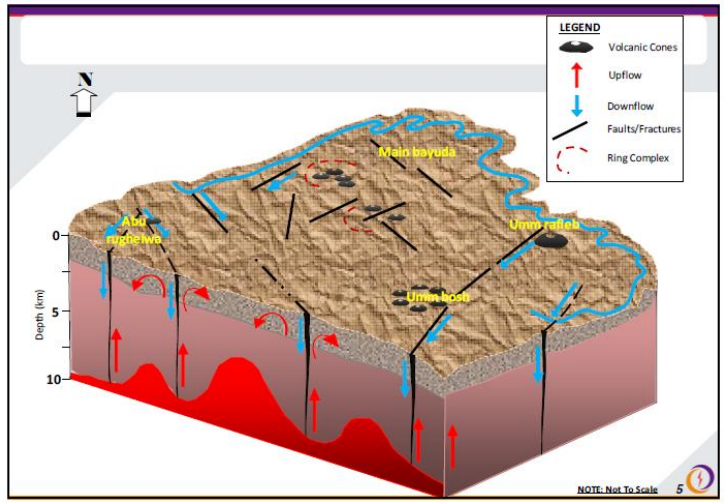
Structure/contents

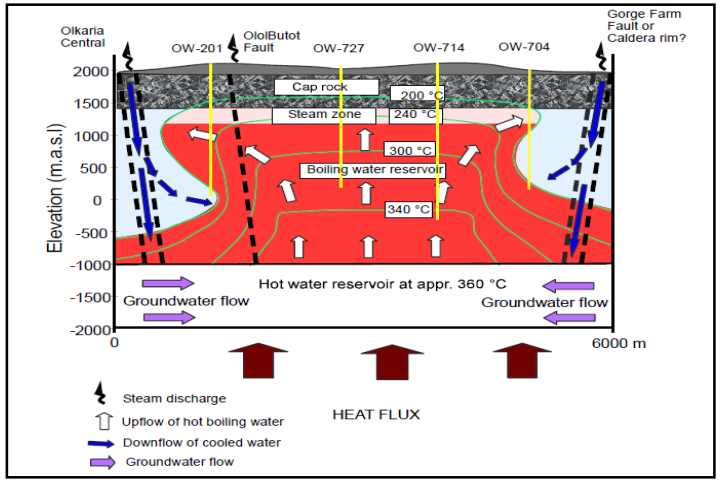
1. Introduction	•Review of previous work, objective & scope of work Geology/structural aspects
2. Methodology& Results	•Work performed Field and Laboratory work
3. Discussion	•Geological conceptual model • Well site
4. Conclusion & Recommendation	•Additional works •Challenges & mitigations •Appendices

GEOLOGICAL CONCEPTUAL MODEL

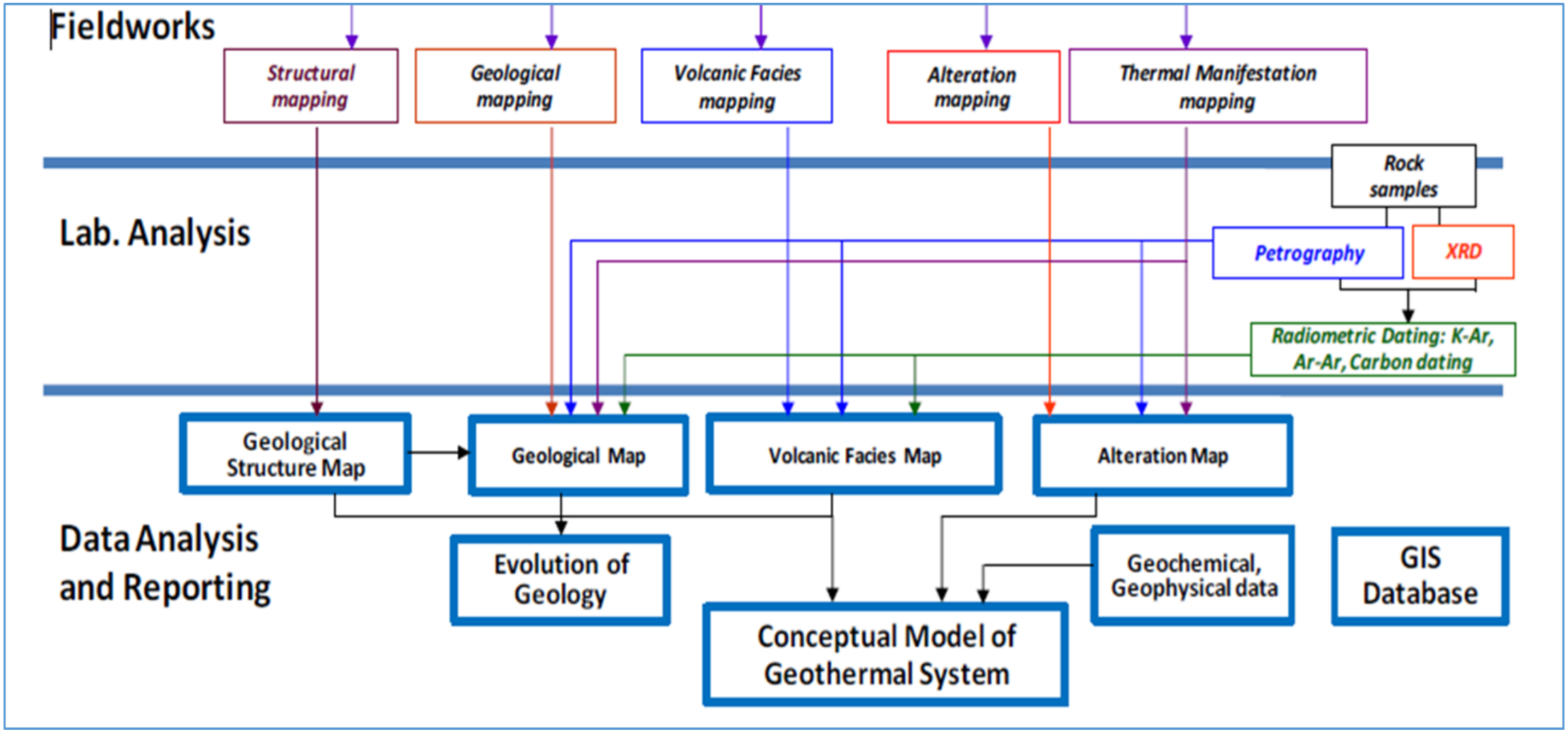
- Demonstrate an understanding of the geology,
- Illustrated with cross sections and drawings.
- Heat source and depth
- Flow Paths/Directions and Structural Controls
- Temperature-Upflow and Outflow
- Well targeting
    - A narrative description of

  the rationale for selecting the proposed target(s).
- Refined with more data





WORKFLOWS


Fieldworks
Structural mapping
Geological mapping
Volcanic Facies mapping
Alteration mapping
Thermal Manifestation mapping
Lab. Analysis
Rock samples
Petrography
XRD
Radiometric Dating: K-Ar, Ar-Ar, Carbon dating
Geological Structure Map
Geological Map
Volcanic Facies Map
Alteration Map
Data Analysis and Reporting
Evolution of Geology
Geochemical, Geophysical data
GIS Database
Conceptual Model of Geothermal System

CONCLUSION

- ✓ Important activity towards geothermal resources identification
- ✓ Aimed at identifying geological phenomena and understanding geothermal system parameters
- ✓ Geological exploration is a step-wise activity
- ✓ Requires resources: personnel, tools & equipment, budget and approvals
- ✓ Effective field work, laboratory data analysis, interpretation and report writing
- ✓ Geological report, conceptual model and well targets
- ✓ Success of geothermal exploration depends on geology

END

Thank you

INFORMATION

Name of course: SDG Short Course IV on Exploration and Development of Geothermal Resources

Location: Lake Bogoria and Lake Naivasha, Kenya

Timing: November 14-December 4, 2019

Organized by: United Nations University Geothermal Training Programme (UNU-GTP) and Kenya Electricity Generating Company PLC (KenGen)

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Presentation author(s): Risper Kandie

Kenya Electricity Generating Company PLC (KenGen)

Email; rkandie@kengen.co.ke

Website; www.kengen.co.ke