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INTRODUCTION TO SURFACE GEOLOGICAL MAPPING IN A GEOTHERMAL ENVIRONMENT

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1 INTRODUCTION

A geological map is a precisely oriented scaled down diagram of the earth's surface. Its position on earth is shown by lines of latitude and longitude or geographic boundaries. Sizes, orientation, and positions of geologic features can be compared exactly with those of other maps (Compton, 1967, 1985). Rock units and structures are identified in an explanation, which also shows the age sequence of the rock units. Contours and symbols for waterways, roads, and buildings make it possible for one to find geologic features shown. An example of a geologic map is shown in Figure 1.

2. GEOLOGIC MAPPING

Geologic mapping is a means of discovering geologic features that include rock types, contacts, age relations, and structural patterns, and seeing the features in three dimensions (Figure 1). Geologic mapping results in the preparation of a geologic map and the development of a geologic history for an area. A geologic map thus shows the following:

- Distribution of rocks at the surface
- Geologic structures
- Cross section in distribution of rocks in the subsurface
- Age relations

Selecting a field study
A study area is selected to answer specific geologic questions based on literature review or identified interests. In case of geothermal investigations, there could be an interest to study an area in more detail the geology of known geothermal area or an area suspected to have geothermal manifestations.

Reconnaissance
It is usually recommended that an area is reconnoitered before the main field work. The main purposes for reconnaissance are:

- To make sure the area is suitable for the planned study;
- To enable proper planning of the field campaign in light of time and funds available.

Thus, reconnaissance will result in the assessment of the road network and accessibility, land ownership, accommodation, terrain, and general strategy on how and when to commence the study.

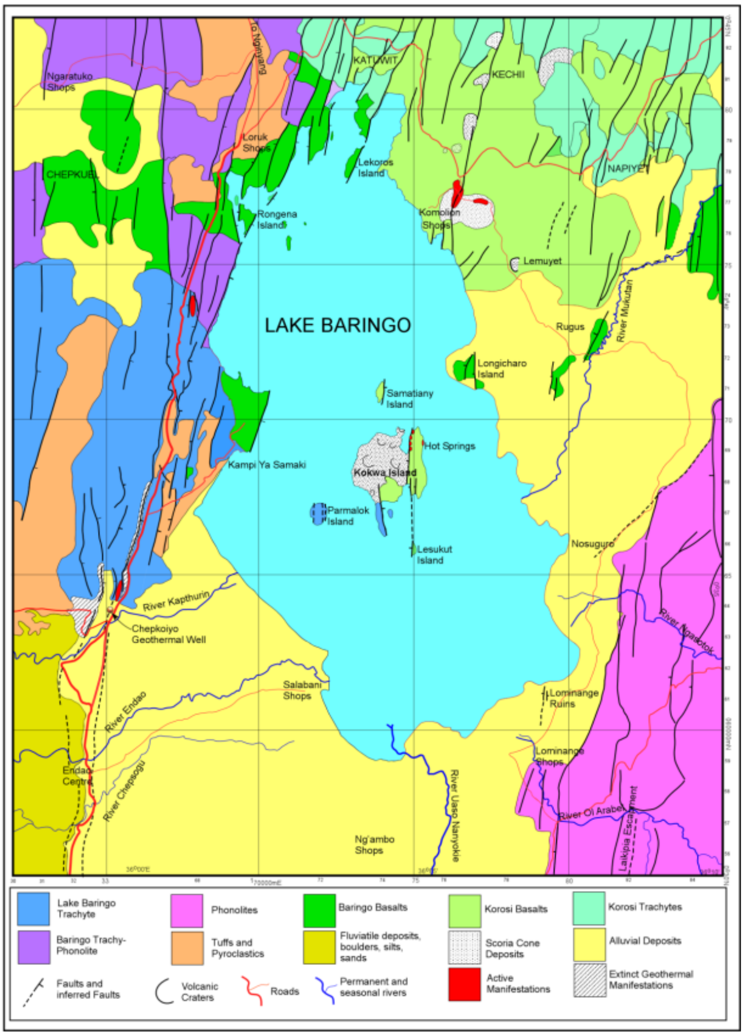


FIGURE 1: Geological map of the Lake Baringo Geothermal Prospect (Omenda, 2006).

3. FIELD WORK

Field work requires the following equipment to be accomplished: base maps (topographic or planimetric), air photos and or satellite imageries, notebooks, pencils, compass with clinometers, GPS, hand lens, camera, dilute HCl acid and geologic hammer. As rock units and other features are encountered, their exact positions and structural features are marked on the map. The localities are numbered to relate them to the notebook notes.

What to map:

- Rock types and Contacts
- Shape of the rock bodies
- Note the sequence and relative ages
- Note primary porosity and permeability
- Note the weathering and their patterns
- Note depositional or magmatic flow features
- Structure
    - Folding - dip, strike, deformation, orientation of grains (Figures 2 and 3)
    - Joints – attitude, size, open or closed
    - Faults – look for slickensides, fault gouge, breccia and visible displacements

- Geothermal manifestations

Note:

- Strike is the geographic alignment of any horizontal line on a planar surface
- Dip is the angle of slope at right angles to strike (maximum slope of the surface).

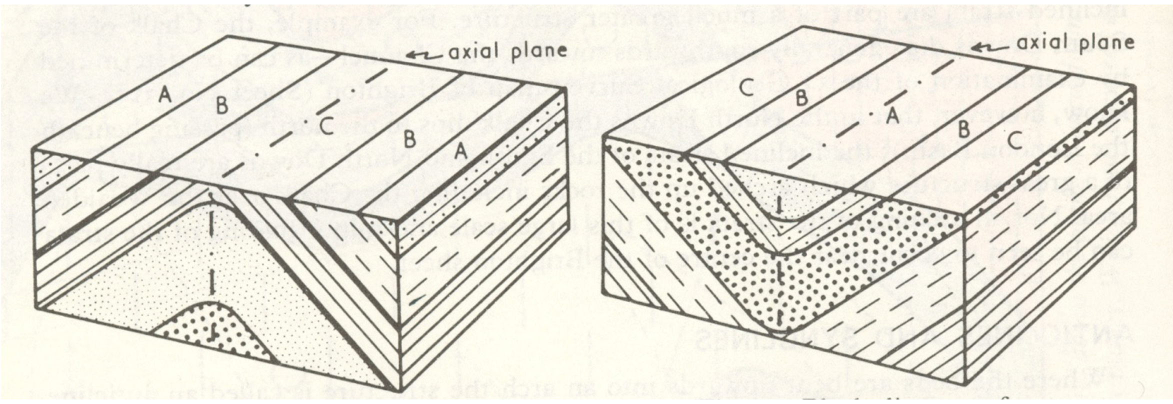


FIGURE 2: Drawings showing folded strata forming anticline and syncline


FIGURE 3: Photo of a folded formation in the field (Homes, 1978)

Mapping rock outcrops
For sedimentary rocks, depositional structures, grain types and sizes as well as fossil contents must all be recorded. All the features listed above must be checked and care should be taken that only 'in situ' rocks are mapped.

Mapping volcanic rocks is particularly difficult because of the following:

- Few fossil if any making correlation difficult
- Rapid lateral changes of the rock types often occur
- Different outcrops may consist of rocks of similar appearance
- Faulting is common which causes offsets of bodies
- Many volcanic rocks are deposited on slopes resulting in variable thickness and extent

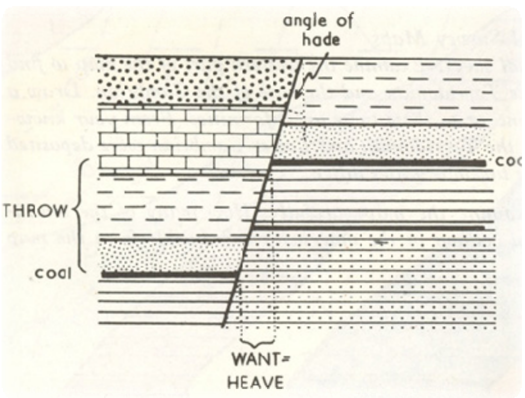
Mapping in a volcanic terrain, therefore, requires the following to be noted:

- Lava flow surface patterns to determine provenance
- Colour and mineral composition
- Nature of the lava flow and thickness
- Presence of dikes, sills or any other intrusions
- For pyroclastic rocks, composition and size of the clasts should be noted; thickness of the beds should also be recorded.
- Note degree of compaction of the pyroclastic beds and any cementation if present
- Record occurrence, orientation and nature of explosion vent (craters, caldera, vents etc.)
- Note any association between volcanic vents and local structures

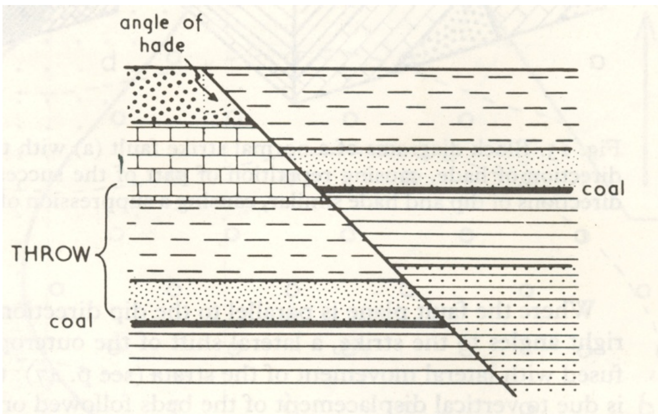
Occasionally, rock samples may be required for laboratory analyses. It is recommended that fresh and representative rock samples are collected. The size to be collected is determined by the purpose for which the sample is required. Samples for petrochemistry are usually large if the rock has large grain sizes.

Mapping of faults
Faults can be easily recognized by the presence of visible displacements (Figure 4). However, in many outcrops, such features may not be apparent. In such situations, therefore, inferences are made based on observed features on the surface. These include scarps, stream offsets, alignment of hot springs or thermal features (fumaroles, hot grounds, altered grounds), straight river courses, unknown lineation in aerial photographs.

A: Normal fault



B: Reverse fault



C: Strike slip fault

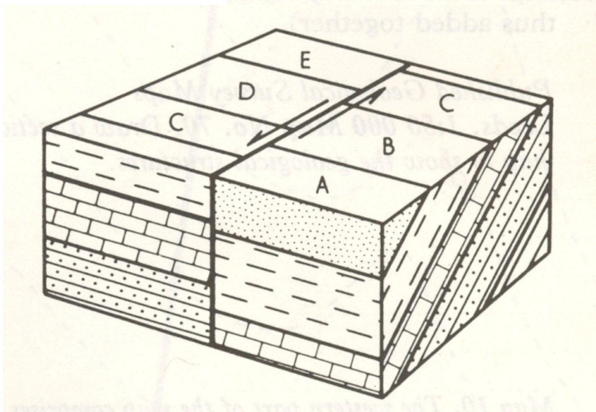


FIGURE 4: Figures showing different forms of faulting (a, b, c)

Mapping hydrothermal eruption features
What to map should include the following:

- Craters if visible; their sizes, orientation, location, depth, and shape

- Nature of the erupted products; distribution, composition, thickness, shape of clasts, altered materials
- Note age and frequency of eruptions by use of tephrochronology
- Surface alteration and stunted vegetation

Mapping geothermal manifestations/discharge features
The following features should be mapped and their locations described:
- Fumaroles and discharge temperatures
- Hot springs – measure flow rates, temperatures, pH
- Hot grounds and their temperatures
- Altered grounds (active and extinct)
- Hydrothermal deposits (geyserite, silica sinter, travertine, metallic deposits, sulphides)
- Sulphur deposits around fumaroles

Use of aerial photos in mapping
Aerial photographs aid geological mapping in the followings ways:
- Can be used as a base map on which geological and structural features are mapped.
- Provides information on access and location of features
- Repeat aerial photos may be used to monitor changes on surface geology or surface thermal activity.

4. INTERPRETATION

Information is shown on aerial photos by:
- Tone
- Relief
- Colour

5. CONCLUSIONS

Geological mapping requires good observational skills and relies heavily on the geologists experience and interpretational capability.

REFERENCES

Compton, R., 1967: *Manual of field geology.*

Compton, R., 1985: *Geology in the field.*

Holmes, A., 1978: *Principles of physical geology.*

Omenda, P. 2006: *Geology and geothermal potential of the Lake Baringo.*