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GEOLOGICAL FIELD MAPPING

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ABSTRACT

A map showing the distribution of rock units and structures across a region representation, usually on a plane surface is termed a geological map. A map showing the occurrence of structural features across a region, the distribution of rock units, and their type and age relationship is termed a geological map. Geological field mapping is the process of selecting an area of interest and identifying all the geological aspects of that area with the purpose of preparing a detailed geological report which must include a map. The three basic reasons why geological field work is carried out include exploitation of natural resources, as a requirement of the government and for academic purposes. Good geological mapping should be executed in three phases; planning, data collection and reporting. Certain parameters must be considered when mapping geology, geological landforms, structures and geothermal manifestations the most important being detail, accuracy and precision. The resulting geological map should be compiled and interpreted with the input of all parties involved including expertise advice from those who have adverse experience in geology as well as other related disciplines.

1. INTRODUCTION

A *map* is a visual representation of an area - a symbolic depiction highlighting the relationships between elements of that space such as objects, regions and themes. A map showing the distribution of rock units and structures across a region, usually on a plane surface, is thus a geological map.

Geological field mapping is the process of selecting an area of interest and identifying all the geological aspects of that area with the purpose of preparing a detailed geological report and a map to summarize the report. A geological map will thus show the various rock types of the region, the structures, geological formations, geothermal manifestations, age relationships, distribution of mineral ore deposits and fossils etc. and all these features may be super imposed over a topographic map or a base map. The amount of detail shown in a map depends largely on the scale and a smaller scale will naturally disclose finer detail. Basically, the quality of a geologic map will depend upon the accuracy and the precision of the field work. Further still quality depends on the completeness with which certain data, both geologic and geographic are presented on the maps; and on the care with which scale, colours, conventions, etc. are chosen to give the best results (Eckel, 1902). With the development of technology however, geological maps today are more precise than ever as a combination of accurate satellite imagery, aerial photographs, high tech geological equipment and Geographic Information Systems (GIS) advancements are applied.

The interpretation of a geological map depends on one's training, interest and the techniques used. It is also fundamental to be able to visualise scenarios that may have been involved during the formation processes of the features displayed as this forms an essential foundation for the analysis of geological maps. The ability to form a three- dimensional image from a two dimensional plan is in real sense the major part of geologic map interpretation (Bolton, 1989).

2. OBJECTIVES OF GEOLOGICAL FIELD MAPPING

Principally there are various reasons why geological field mapping is carried out all of which entail collecting variable amounts of field data. These reasons can, however be summarized into three broad objectives which may sometimes be interconnected (Figure 1): natural resources, government mandate and academic objectives.

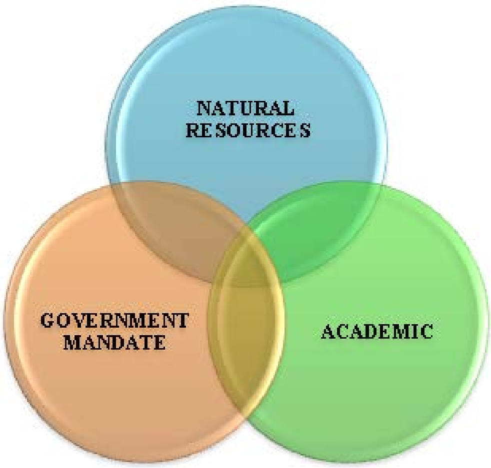

FIGURE 1: Objectives of geological field mapping

2.1 Natural resources

These are naturally occurring materials that exist within the earth's crust and are extracted mostly for economic purposes. Exploitation of all natural resources requires the appreciation of basic geology and optimum utilization of a potential area requires that the resource is mapped out. Understanding the spatial distribution and deformation of rock units at the surface is critical in order to develop 3-dimensional models of the subsurface geology. Mineral and oil exploration proceeds in this way, particularly when considering the siting of boreholes (Eppler, 1997). In geothermal fields, the geology of the area has to be thoroughly investigated and understood using a combination of geological, geophysical and geochemical methods before a decision is made on the productivity of that area. Geological mapping is usually the first task in any reconnaissance study as the question of whether or not a geothermal system exists can be answered using geological studies. Geophysical investigations answer the question of the extent of the system while geochemical investigations are used to estimate parameters such as the temperature of the system.

2.2 Government mandate

In order to better understand an unknown area, geological mapping is carried out by learning and/or government institutions. The maps created are thereafter used as references for planning purposes in development projects, prevention of adverse destruction during natural disasters such as earthquakes (hazard preparedness) impact assessment studies, proper utilization of resources etc. Most government structures have a geology ministry/department that ensures that geological maps are available, that they are accurate and updated whenever changes arise. Ultimately all governments have an important role to collect and administer geological data, information and knowledge while protecting and preserving the area in question at the same time.

2.3 Academic

The third reason is to shed some light on the processes that have moulded the earth to what it is today. Processes in the subsurface are not fully understood and the in mapping geological features on the surface we get some insight into the more complex systems that we do not see. Therefore, in dealing with a limited data source, geologists are forced to leave no stone unturned in acquiring the basic data for developing models of geologic history and process, and, in contrast with many other sciences, to use a healthy dose of imagination in interpreting what is almost always an incomplete data set.

(Eppler, 1997). Many earth science institutes work tirelessly in creating models and proposing theories that may have explained various geological formations, structures and lithologies, where geological maps have been the foundation of these studies.

3. PHASES OF GEOLOGICAL MAPPING

Field mapping projects are carried out in three phases which have a stepwise relationship (Figure 2).

FIGURE 2: Phases of geological field mapping

3.1 Planning / research

This phase of mapping is mostly carried out in the office although a short reconnaissance field trip may be included. Once a field has been identified for mapping, it is only rational to learn everything in its regard so as to make a workable field programme. A field programme is a step-by-step guide that outlines the time to be spent in the field and the objectives of each day thus ensuring successful and satisfactory results. Compilation of all available and relevant data is implemented, in an effort to avoid duplication of work and most importantly simplify the field study. The number of days spent during the research phase may vary based on the purpose of the study, the detail required and availability of funds. All possible geological reports and data, including aerial and satellite photographs, maps whether topographical, base maps, legislative boundary maps etc. must be obtained. The most important document however is the official approval by a government office and/or a local community. Without this one may be met with hostility and lack of cooperation by the locals and this may lead to an unsuccessful field study. A budget must also be prepared indicating the number of people to be involved in mapping, their daily allowance, fuel costs if vehicles are to be used, consumables and a miscellaneous kitty should be included. It is wise to involve the local community when employing casuals or language translators as they understand their environment better than anyone else and will thus be quick to pinpoint areas that maybe of interest. Furthermore, they are in the best suited to relate historical events where necessary. Issues that may hinder optimum productivity such as bad weather, wild animals and events of sudden sickness must be taken into consideration and planned for appropriately.

3.2 Observing / mapping / collecting

This phase is focal in any geological field mapping and is carried out in the field for the sole purpose of collecting data. This data may be collected in the form of photographs, measurements, notes and physical samples. Therefore, one must be fully equipped with all the necessary tools, be physically psyched and mentally prepared to make note of not only geological features but of the entire surrounding. For example, phreatophytes may be used to locate structures especially when they grow in a certain alignment. When good strategy is involved during the planning phase, unfortunate incidences in the field are addressed promptly with no major disruptions of the field program. In tropical countries such as Kenya, it is advisable to plan for field studies during the dry seasons. Thus it is in the best interest of everyone to commence mapping work very early in the morning so as to accomplish a substantial amount of work before the temperatures rise too high. In colder climates such as Iceland mapping is usually planned for the summer and may begin at any time of the day and extend well into the night as daylight is prolonged to about twenty hours. Thus there should be no strict working hours in the field and this should be agreed upon among the field crew. Teamwork should be encouraged given that more observations are likely to be made and geological contentious issues discussed. A mapping project must be qualitative as well as quantitative. Accuracy whilst taking readings should be emphasized and no amount of information is too much therefore all possible data should be collected.

3.3 Reporting

It is often said that a report is as good as its data and thus the need to collect good accurate data cannot be overemphasized. Ultimately when all possible available data has been collected it is taken back to the office or laboratory for sorting, interpretation and analysis. This phase is the most challenging of all three as wrong analysis or misinterpretation of data can lead to an inaccurate report and in consequence misinformation. The resulting map or model is in most incidences drawn by persons of another section (for example cartography) who may have had no involvement in the field whatsoever. Thus it is crucial that the data collector, in this case the geologists, work closely with those involved in actual drawing of the map, since they can select the data that is relevant for final presentation in the map and that which is not.

4. TOOLS AND EQUIPMENT USED IN GEOLOGICAL FIELD MAPPING

- *Maps:* During the research phase all existing data and maps of the field in question are collected. All suitable maps available whether physical, political, relief, road, physical, and topographic should be carried to the field as it is possible that details in one may not be present in another. Most importantly for geological fieldwork, a geological map is expected to be handy especially as a reference. Depending on the areal extent of the field and the detail required, the scale of the map is an important aspect to consider.
- *Aerial photographs and stereoscope:* This 3D imagery tool is very vital for all geological field work especially where large features such as volcanoes, calderas, craters etc. are involved. In addition photos are also used to pinpoint thermally anomalous areas in geothermal fields when infrared thermography is applied. These photographs are studied with the aid of a stereoscope and are put to use before and during the field study; for planning in the case of the former and for confirmation purposes in case of the latter. Where aerial photographs may not exist, satellite imagery may be used although it may not possess the fine detail as seen on the aerial photographs.
- *Compass/Clinometer:* A compass is an instrument used for determining direction and has recently been supplanted by modern devices such as the Global Positioning System (GPS). However, when acquiring a clinometer, it is advisable to purchase one that has a built in compass in it. This is for the reason that a GPS can at times malfunction or it may not locate satellites in areas of thick/dense forest cover. A clinometer is an instrument used for measuring inclination, tilt and elevation of rock outcrops. This is particularly important in areas that have been subjected to tectonic movement. These days, however technology advancement ensures quick and easy measurement of strike and dip of a surface (bedding plane, foliation, fault plane etc.) in a single action. Unlike a conventional compass or clinometer, which needs two actions to fulfil a measurement, you place a GeoClino on a surface and measure the strike and dip that significantly saves time and labour. The build-in GPS makes it possible to measure latitude and longitude that can be saved in the GeoClino-G memory along with other measurements. It is also possible to use GeoClino as a normal GPS receiver.
- *GPS (Geographic Positioning System)* is a satellite based navigation system comprising three basic parts; the satellites in space, monitoring stations on earth and the GPS receivers. This equipment is used in geological field mapping for finding one’s position, mapping lithologies, tracking structures, measuring elevation, storing sampling points and descriptions of formations when samples are collected. The GPS functions and capabilities are improving rapidly with advancement in technology and as such it is important to purchase one that is relatively modern.

- *Geological hammer* is basic equipment for any geologist as it is the tool used for collecting samples (Figure 3). The best geological hammers are the ones with a piece chisel head made of hardened steel and a rubber coated shock reduction handle. For harder formations, a crack geological hammer forged from fine grain carbon steel with fibreglass shaft fitted with comfortable shock-absorbing rubber grip, is recommended.

FIGURE 3: Chisel head and crack geological hammers

- *Hand held lens* is used to make the first analysis of rock samples in the field before further analysis is performed in the laboratories. The analysis needs to be detailed and descriptive giving all properties of the sample: rock type, colour, texture, identifiable mineralogy, alteration as well as the physical properties such as folding, foliation, intrusions, layering etc.
- *Sample bags* which best suit geological samples are canvas in fabric have a sewn in tie tape and a label tag on the outside to insert the sample number and location point. Plastic bags may be used where the sample is soft, disintegrated or wet.
- *Measuring tape* is important for taking actual measurements of lithologies and structures. For instance in lithologies that exhibit layering, it is necessary to measure the thickness of each layer precisely, as this can be used as a correlation tool with other similar sequences that may be encountered.
- *Field notebook, masking tape, marker pens:* All important observations must be written down in a concise, orderly and legible manner. The field note book should be hardcover for ease when writing and should easily fit into a pocket. Masking tape and marker pens are used for labelling samples before they are put into the sample bags.
- *Field camera* is the only back up memory in addition to the notebook. It is very important to take photographs of all interesting features ensuring a scale is used in each instance; video clips can also be of use. One must also remember to take a GPS reading for each photograph taken. Photographs are important for descriptive purposes especially during report writing and for making presentations.
- *Safety clothing*: These include sturdy shoes, clothes that are tough in fabric preferably jeans or khaki, hat and sunglasses to protect one from the sun a bag pack, plus a raincoat and wellington boots just in case of wet environments. Safety glasses and gloves are important especially when hammering rock samples. Safety clothing should aid one to be more effective by being comfortable and safe at the same time.
- *First aid kit:* Safety in the field is always a priority; nevertheless, accidents cannot be ruled out thus the need to be prepared with a first aid kit. Furthermore, it is crucial that at least one person in the field crew be trained in basic first aid techniques.
- **Geologist imagination* is the most expensive equipment of all. Most of the earth processes have never been witnessed in an actual sense. Thus it took the imagination of the early scientists to have the models we have today. Most of these models have been tested over time and have been proven to be true. Consequently, when carrying out geological field mapping, one needs to use their imagination when viewing geological formations and structures.

5. PARAMETERS TO CONSIDER IN GEOLOGICAL MAPPING

Geology. When mapping rock types, it is important to have a carefully laid out plan for the entire location so that traverses can be made without leaving out some areas. A careful study of aerial photographs and topographical maps can aid one to avoid areas that are impractical to traverse on foot or impossible to climb because they are too steep. In areas where there is thick soil cover, riverbeds, valleys or exposures on hill tops are sort after for outcrops.

Collecting fresh samples is a process performed carefully, ensuring that the sample is not altered. The sample size depends on its intended use, be it for binocular, petrographic, X-ray analysis, whole rock analysis or just for reference. However, a sample should not be too big as to become a problem to carry while in the field. When acquiring a sample for whole rock analysis, it is advisable to break it using another rock from the same formation to ensure that it is not contaminated by metals from the geological hammer.

Geological descriptions must be unambiguous such that other observers given the same sample would describe it the same way (Wyllie, 1999). Moreover, every fine detail must be included whether it is deemed geologically relevant or not.

Strike and dip are a technique of relating the orientation of a plane in three dimensional spaces. The technique is usually applied to the orientation of tilted layers of rock and thus one can easily see the disarticulation a formation has undergone. As mentioned earlier a clinometer is used for these measurements which should be carried out more than once with utmost precision.

Geological landforms. Geological landforms in this paper refer to features such as mountains/hills, calderas craters, canyons etc. The magnitude of these formations (usually large) can be estimated from aerial photographs and maps prior to the actual field work (Figure 4). The dimensions of these formations must therefore be obtained by actual measurement. The recommended method is to traverse the formation on foot while using a GPS to track the movements. For example, to map the dimensions of a caldera it is in best practice to first measure the rim by walking around it ensuring the GPS is in tracking mode. Since the elevation will be known by walking up the caldera one should then walk into it for further measurements. All lithologies should be mapped both in the interior and exterior of such formations. In some instances, landforms such as calderas and craters may not be obvious on the surface due to erosion and weathering which may leave only a few exposures on the surface. If such outcrops are ignored it would be difficult to realise the connection if another exposure of the same kind is found in another location. Needless to say, a structure can easily be left out if work is carried out hurriedly.

Geological structures (faults and fractures). Faults and fractures always indicate movement within the earth's crust. They are distinguished from each other by whether displacement (lateral or vertical) has taken place; faults show displacement whilst fractures do not. Differences aside, the mapping of these structures needs to be done meticulously due to the fact that these structures may easily be confused with simple erosional surfaces. Erosional surfaces may sometimes be an indication of an underlying structure. The disparity is whether any observable disturbance can be seen in the bedrock. Structures like geological features may not always be obvious on the surface. In volcanic areas, they may manifest as volcanic centres or fumaroles oriented in a linear direction which become obvious once a map is compiled. Thus it is imperative to be accurate in measuring all formations and structures with well calibrated equipment so that if extrapolations are to be made for modelling purposes the error margin is very slim.

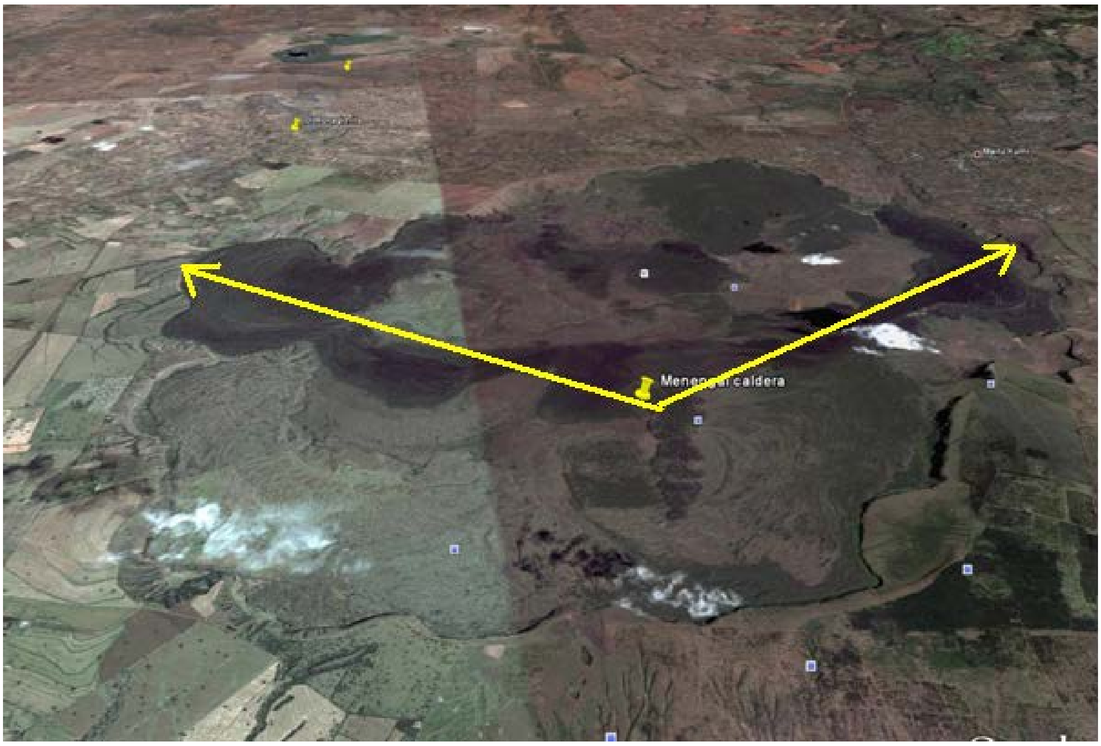

FIGURE 4: Satellite image of Menengai caldera. The dark lava flows on trachytic eruptive centres imply orientation to the northeast and northwest and these can be inferred as structures.

Geothermal manifestations. Geothermal manifestations, whether hot springs, fumaroles, altered or hot ground, geysers, steam jets or sulphur deposition, must be mapped and their extent measured. All observable characteristics should be fully described and photographs taken. Intrusive rocks must be analysed in detail making note of their composition, quantity, orientation and if any sequences can be identified they should be numbered accordingly. All new mineralisation should be sampled regardless whether the same formation has been sampled elsewhere.

6. COMPILING GEOLOGICAL MAPS

With the aid of GIS (Geographic Information Systems), maps of good quality and great accuracy are produced. Evidently it is important to consult with the GIS department before field work to calibrate the GPS in a format/units that can easily be used with their software. Nonetheless, it is important for a geologist to draw a simple sketch map during field work for comparison purposes.

7. INTERPRETING GEOLOGICAL MAPS

Once a map is complete, the most important task ahead is interpreting it correctly. A map is basically a visual summary of an entire report and the two should complement each other. When the interpretation process is at hand, it is crucial to have group discussions with all those involved in the actual fieldwork. It is also deemed important to have discussions with those who are experienced in field of geology as well as other related scientific fields.

8. CONCLUSION

The following can be said to summarize geological field mapping:

- For geological field mapping to be carried out efficiently, it is essential that proper planning is executed.
- Once in the field, it is also important to be as detailed as possible in all descriptions, to be keen and observant.
- Measurements must be performed meticulously and, if necessary, more than once for confirmation purposes.
- Team work must be adhered to, throughout the entire process.

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