# FIELD GEOLOGY

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## Contents



## Summary

This article details some of the many techniques available to modern geologists and attempts to detail the primary applications of these techniques to combined geological studies. The subject of field geology has been divided into the four broad topics of geology, geochemistry, geophysics and geofluids to facilitate explanation of the topics. It is stressed, however, that these topics are seldom approached in isolation and modern geological surveying utilizes components of all these sub-disciplines.

In recent times, advances in computing and analytical equipment have greatly increased the reservoir of techniques the geologist can access in any survey. Whilst this is a welcome development and can contribute to the speed of geological surveying and, in some cases, its accuracy, this contribution primarily addresses the main classical techniques since these are the foundations on which further developments are made. More modern techniques are detailed where they have contributed significantly to the efficient measurement of data, accuracy of survey or represent likely future trends in field geology.

Naturally, there are many more techniques available to the field geologist than are covered here, and many fields have been underrepresented in the interest of brevity, but a representative cross section of techniques available is provided. The field geologist is now a competent multitasker, able to readily interchange between the rigid sub-disciplines of the subject. In addition, the requirement now exists that the geologist is a competent computer analyst, engineer, chemist, and physicist. It is through cross fertilization of sciences that some of the major developments of modern geology have come about, and there is little doubt that this will be responsible for the future development of the field geologist.

The data obtained in the field, post-field processing and some level of interpretation are detailed, with several references provided for further reading in the individual topics.

## 1. Introduction

The application of the scientific method governs the overall approach to the measurement of geological data and any subsequent analysis and interpretation of it. The range of tools available to the field geologist has advanced in leaps and bounds, particularly in the last century with the development of the oil industry and advanced computing facilities. Whilst single specialization geologists exist, and are very much valued, the modern geologist has generally followed the trend of computing: becoming capable of multitasking. Modern developments in analytical techniques have generated a multitude of geological consultancies, whose role is to take the enormous amount of data generated in the field, interpret them and synthesize a realistic geological model based on all of the information sources. It has, therefore, become more important to specify clearly the target of geological analysis, since it is possible to carry out advanced analyses almost *ad infinitum* on a target sample suite without contributing to the solution of any given problem.

Geologists must be expert in the application of many techniques, know what data can be obtained from them and how reliable those data are.
This report details some of the techniques currently available to the geologist for field surveying and data acquisition. The emphasis is very much on field techniques. Laboratory and large-scale analyses generate vast data sets that the geologist must process and interpret but these are not detailed in this review: only those techniques available in the field and that can be completed by a single field geologist or a small team are included.

In all cases, the techniques described rely on the skill not only of the equipment operator but also of the geologist who has mapped the surface geology and targeted both the sample site and the techniques to be applied. The geologist has become much more skilled at the detailed planning of support analysis projects to field mapping. Techniques that rely upon the chemical analysis of minerals, rocks or fluids are invariably highly dependent on the selection of controlled samples. A detailed knowledge of the limitations of a technique, what it is likely to tell you in terms of geological structure, chemical variation, age or geological history must be assessed by the geologist before embarking on what can be quite expensive analytical schemes.

## 2. Geological Surveying

Geology is composed of many sub-disciplines (Table 1), each with its own specialist techniques and field rationale. Most geologists specialize in at least two fields and must be familiar with the others if they are to accurately carry out a field survey. The reason for this is simple: the failure of the geologist to apply the appropriate technique in surveying will limit the usefulness of the final product. Ignoring any source of information can lead to poorly constrained geological models of the field area. Cross-fertilization between disciplines has given rise to some of the more notable advances in recent years and conferences are more commonly based around multidisciplinary topics to facilitate this.

| **Geological Field** | **Main study** |
|---|---|
| Sedimentology | ancient sedimentary systems and processes |
| Stratigraphy | ages and order of succession of rocks |
| Petroleum geology | petroleum generation, migration, chemistry and exploitation |
| Mining geology | ore deposition, transport and exploitation |
| Mineralogy | the composition and characteristics of minerals comprising rocks |
| Igneous petrology and petrogenesis | the processes of development, chemistry and emplacement of igneous bodies |
| Volcanology | all aspects of volcanoes, formation, chemistry and predictive methods |
| Geochemistry | chemical processes and reactions applied to geology |
| Organic Geochemistry | use of organic chemistry in examining petroleum and environmental systems |
| Hydrogeology | water chemistry, location, migration and exploitation |
| Structural Geology | structural modification of the crust, mountain building processes, plate tectonism |
| Metamorphic Geology | the processes (particularly with reference to pressure and temperature) active during the metamorphism of rocks |
| Palaeontology (& micropalaeontology) | all aspects of the fossilization of and identification of ancient life forms |
| Geophysics | the application of physical field theory to the study or, generally, inaccessible rocks |

Table 1: Sub-disciplines in Geology

### 2.1. What Basic Measurements do Geologists Make in the Field?

#### 2.1.1. Using the Compass-clinometer

The most utilized surveying and mapping tool of the geologist is the compass-clinometer (Figure 1). Geologists have used this simple device to produce some stunning geological maps in the past few hundred years. It is perhaps sobering to look at these maps, generated without the benefit of the techniques available today. Modern techniques have certainly increased the accuracy of field surveying, and the speed with which it can be done, but they are of limited value unless underpinned with basic mapping skills.

The compass-clinometer is, of course, used initially in locating the position of the geologist in the field. Simple triangulation methods (compass is used to sight at least three landmarks which are transferred as bearings onto the map) combined with base maps are utilized to position the geologist to an accuracy, commonly, of 10 m. Such accuracy is obtainable in areas where base maps are accurate and there are sufficient objects on which to triangulate. This accuracy declines in areas where no base maps exist, are inaccurate, where there are insufficient landmarks or visibility is poor.

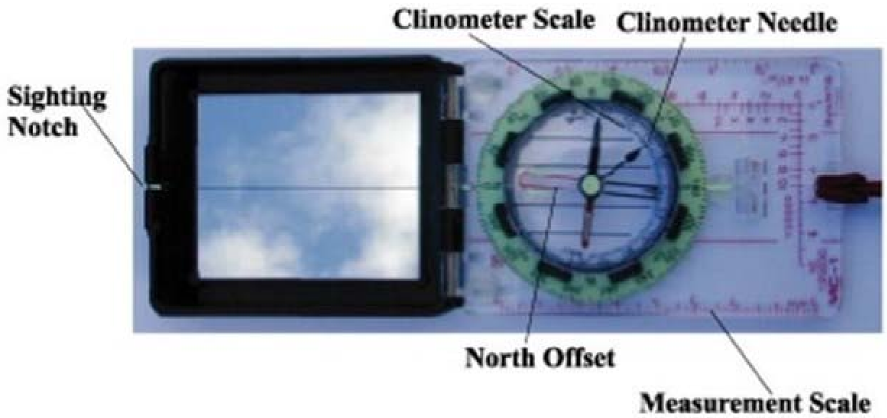



Figure 1: The basic compass-clinometer

The second main application of the compass-clinometer is the accurate measurement of the inclination of 2D and 3D features. Contacts between different layers of rock, igneous intrusions, lava flows, faults, fractures, etc., must all be recorded accurately and in absolute detail if a realistic reconstruction and interpretation of the geology of the area is to be completed. Field measurements are generally vectorial in nature, and the most commonly made are illustrated in Table 2 and Figure 2.

| **Measured parameter** | **Definition** |
|---|---|
| Dip | The maximum angle of inclination of any surface from horizontal |
| Strike: | The bearing of a horizontal line on a surface. The strike of a plane is normal to the dip direction. It is important that a standard method of reporting the strike direction is used: the quadrant of the dip direction must be cited with the strike bearing. For example, a bed striking 090˚ and dipping 43˚ may dip in either direction (i.e. either towards 000˚ or 180˚). Thus the dip must be recorded as 090˚/43˚N or 090˚/43˚S. |
| Plunge: | This is the dip angle and orientation of a linear feature (e.g. a fracture, a fold hinge) |

Table 2: Basic terminology of measured orientation parameters

Measurement of these basic orientation data facilitates the representation of bedding, layering and linear features on a 2D map and also provides the basic information required for the interpretation of spatial relationships between bedding/ layering and other structural, depositional or intrusive features. Measurements on structural features such as faults, folds lineations on fault surfaces and cleavages in the rock are all represented using standard terminology on the base map. A common application of the dip and strike measurements is in the determination of the true thickness of a dipping geological feature. This is a process of simple trigonometry (Figure 3).

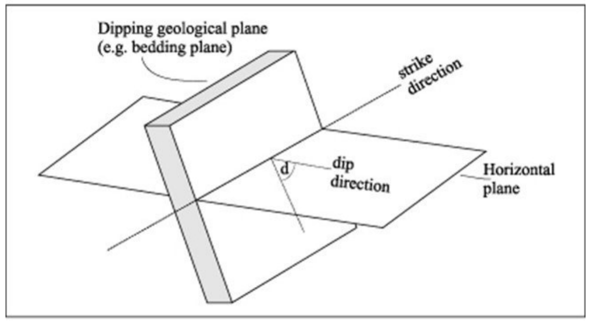



Figure 2: Basic geological terminology: dip and strike of planes. Although strike is commonly measured, the azimuth of dip is often favoured by some geologists - this is the bearing taken along the dip direction.

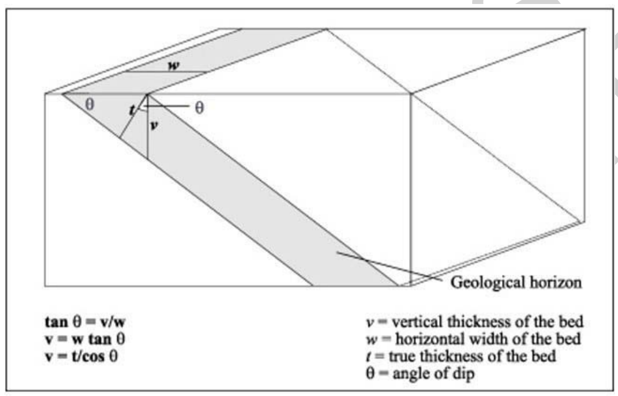



Figure 3: Determination of true thickness of a dipping bedding plane. Measuring the dip angle ($\theta$) of the bedding plane and the width of the outcrop in the dip direction ($w$) allows the true thickness of the unit to be determined by simple trigonometry.

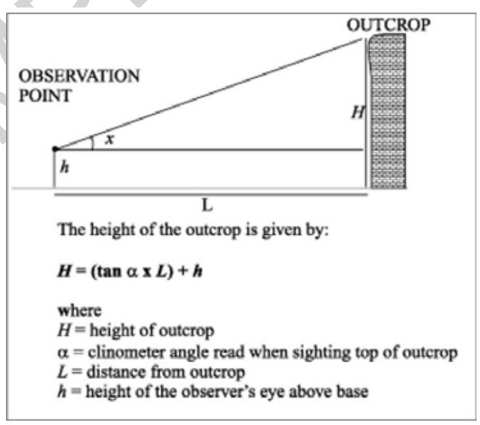



Figure 4: Calculating the height of an outcrop (cliff) using the compass-clinometer. Simple trigonometry and accurate sighting using the compass-clinometer allow heights to be rapidly determined.

The final main application of the compass-clinometer is in the determination of height and relative altitudes of exposures. The compass-clinometer gives the geologist the ability to rapidly determine rock face orientations and heights (Figure 4) and altitude differences between widely separated outcrops. This is used in reconstructing the *z*-dimension of the geological model finally extracted from the data and also in checking the accuracy of the base map contours.

In a single day's mapping the geologist can generate hundreds of locations and measurements using the compass-clinometer. It is essential therefore that these data are recorded methodically and accurately.

### 2.1.2. Improving on the Compass-clinometer

Geologists take advantage of additional equipment now available to increase the accuracy of, or more easily collect, the basic spatial measurements that were traditionally carried out with the compass-clinomenter. The development of cheap, accurate altimeters (commonly forming part of the handheld GPS system) refines the accuracy of the positional data acquisition. This is frequently sufficient to allow the data acquired to be modelled in 3D without the existence of base maps. Most basic geological mapping (that done on printed base maps) requires a positional accuracy of approximately 10 m (this is the thickness of a thin pencil line on a standard base map so any further accuracy could not be represented on the map). This is within the accuracy range of modern handheld GPS systems. Any further refinement of positional or elevation accuracy (for example, using differential GPS) often requires more time than its benefit warrants. More commonly, high-resolution GPS systems are used to carry out initial surveys prior to the main mapping project, or to provide accurate height measurements for precision surveys. They are perhaps most valuable in defining contour heights where none are available and in setting out traverse lines. Where a continuous outcrop is present, traverses are generally employed to measure accurately the spatial relationships between phenomena such as layering, intrusive boundaries and vein systems. Where no outcrop is present, traverses are employed to accurately constrain (commonly geophysical and geochemical) measurements. Traverses are generally oriented in the dip direction (of sedimentary rocks) or normal to the predominant strike of intrusions and igneous contacts.

### 2.1.3. Elevation in Hydrogeology

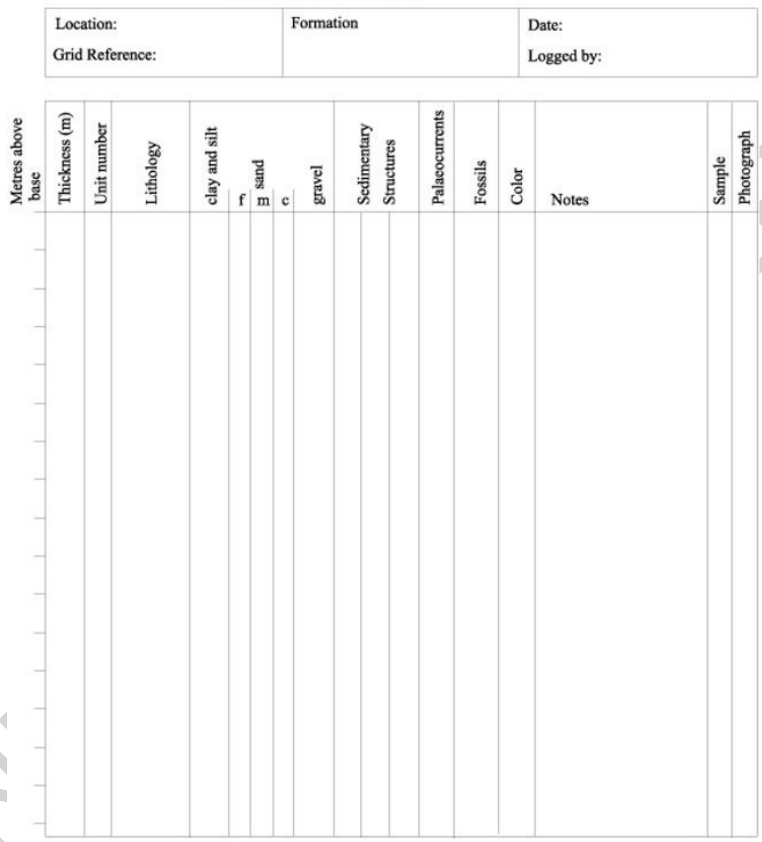
Elevation is particularly important in hydrogeological surveys. The tool commonly used by hydrogeologists to measure this is the surveyor's level. This is a simple-to-operate tool for assessing rapidly the heights at which, for example, water samples are collected. It is essentially a telescope mounted on an adjustable base that allows line of sight through the telescope to be maintained at a horizontal level. Heights are then measured from this level using a graduated staff. Accuracies (i.e., root mean square errors) of 1 cm are common using this technique.

### 2.1.4. Field GIS Systems

The most significant advance to basic spatial field mapping is the integration of field

GIS software with GPS and handheld computer systems. With this, the geologist can collect and plot their data in the field without having to interact to any great degree with the software. Furthermore, these data may be relayed, in real time, to base systems where advanced GIS processing techniques may be applied, the base maps constructed and relevant maps and images transferred back to the geologist as they are needed. Further, where base maps are not available, handheld GIS systems allow the geologist to generate, rapidly and accurately, 3D models of geological features in the field.

### 2.1.5. Geological Logs


| Location: Grid Reference: | Formation | Date: Logged by: |
|---|---|---|

| Metres above base | Thickness (m) | Unit number | Lithology | clay and silt | sand f | sand m | sand c | gravel | Sedimentary Structures | | Palaeocurrents | Fossils | Color | Notes | Sample | Photograph |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Figure 5: Typical logging sheet. Symbology is used to represent sedimentary structures, lithology, fossils, etc., to allow a surprising amount of information to be recorded on this simple template. Examples of symbology can be obtained from Tucker (1995).

One of the main activities of the geologist is determining the vertical and lateral relationships between strata identifiable in widely separated exposures. A methodical approach is therefore necessary in dealing with each component of the succession that is visible. The geological succession is then constructed from observations made at small, spatially disparate, exposures. It is important that every feature is recorded in each exposure since basic features of an exposure may turn out to be the only method of correlating between that exposure and another. Whilst vertical succession is important, similarly the lateral continuity of the strata is important. For example, a river channel deposit is not going to extend for many meters in width; marine shale will grade into a coastal deposit as we approach the palaeolandmass. The method employed by most geologists to record observations at distinct sites is the standard logging sheet (Figure 5). The geologist, to include additional features pertinent to the survey, usually modifies the basic log structure but the basic characteristics of the log seldom vary.

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**Biographical Sketch**

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