Course 01 : Basic Knowledge

1. Topography:

Topography is the technique dealing with the representation of the shape of the ground and the details found on it. (Bernard Dubuisson, 185)

Topography includes two disciplines:

- Topometry: the technique of carrying out field measurements.
- Topology: the science of the shapes of the terrain.

Topography is based on two categories of operations:
- Planimetry: the representation in plane projection of all two-dimensional details of the topographic plan. It involves all horizontal measurements (angles and distances).
- Altimetry: the representation of relief on a plan or map. It involves all vertical measurements.

2. TOPOGRAPHIC WORKS

Topographic works can classified into six main categories according to the chronological order of their execution.

The Topographic Survey:

This includes all operations intended to collect in the field the elements necessary for the establishment of a plan or map. The survey document, after possible digital processing, leads to the production of graphic or digital plans (the reporting phase).

Detail surveying consists of determining, from framework points, the positions of various natural or artificial objects on the terrain. A survey is carried out from observations, i.e., measurements taken with instruments; by extension, 'observations' often refer to the measurement results.

2.1 Topometric Calculations:

These process numerical observations of angles, distances, and level differences to provide plane rectangular coordinates (Easting E, Northing N) and altitudes (H) of terrain points, as well as areas. Conversely, they also allow the calculation of unmeasured values for angles, distances, and level differences, useful for staking out..

2.2 Topographic Drawings :

A topographic drawing is the conventional representation of terrain at large scale. According to data collection and processing methods, three types of plans are distinguished:

- **Graphic plan**: obtained by plotting descriptive elements of the terrain onto paper. Its precision is limited by manual drawing, typically 0.1 mm.
- **Digital plan:** a computer file of point coordinates and descriptive elements. This allows drawing at different scales with CAD tools, with accuracy depending on data acquisition.
- **Digitized plan:** a digital plan partly derived from a graphic plan.

The term 'topographic plan' generally refers to a plan representing visible natural or artificial terrain elements with conventional representation of altimetry.
The scale (E) of a plan or map is the constant ratio between a measured distance on paper (P) and the corresponding ground distance (T): E = P/T.

Types of scales:
- Small scale: E ≥ 1/100,000
- Medium scale: 1/10,000 ≤ E < 1/100,000
- Large scale: E < 1/10,000 (e.g., 1/5,000; 1/2,000; 1/1,000).
- Very large scale: 1/500, 1/200, 1/100, 1/50.

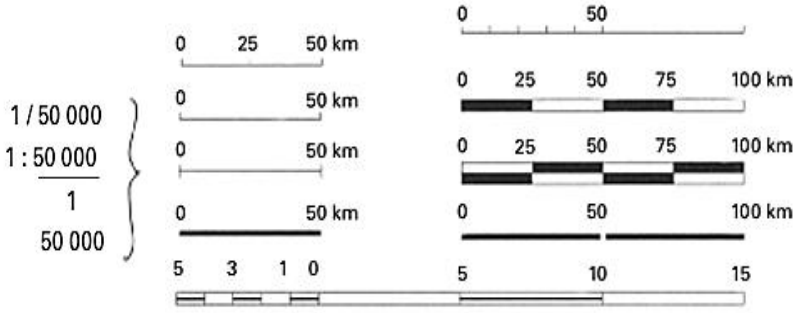


Figure 01 : Numerical and Graphic Scale

2.3 Development Projects

Projects modifying planimetry and altimetry, such as land development (land consolidation), subdivisions with roads and utilities, road and railway layouts, water management (drainage, irrigation, canals, ditches, etc.).

2.4 Implantations

Development projects, usually based on topographic data, must be carried out in the field. The surveyor transfers the planimetric and altimetric elements onto the terrain.

2.5 Monitoring and Control of Structures

Structures such as dams and bridges often require monitoring at regular intervals according to their function (subsidence, safety, etc.)..

3. GEOGRAPHIC COORDINATES :

The globe is divided by a reference system of orthogonal lines: meridians (great ellipses through the poles) and parallels (circular lines parallel to the equator).

The equator and meridians are graduated in degrees or grads.

A point P is located by its longitude and latitude. Longitude is the arc of the equator between point P's meridian and the prime meridian; latitude is the arc between the equator and point P along its meridian.

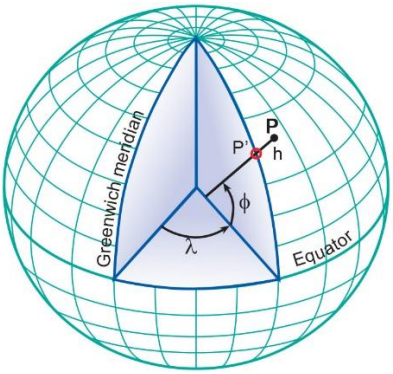


Figure 02 : Geographic Coordinates

4. PROJECTION SYSTEMS

The transformation from Earth's physical surface to a plane is done through projection, which refers to geometric perspective.

4.1. Shape of the Earth:

The Earth appears spherical but is slightly deformed by centrifugal force from its rotation. This results in a flattening of 11 km at the poles and a bulging of 11 km at the equator.

Geodesy studies the Earth's shape, dimensions, and gravity field. It determines coordinates in a unique reference system.

For measurements, geodesists use two mathematical surfaces: the ellipsoid and the geoid.

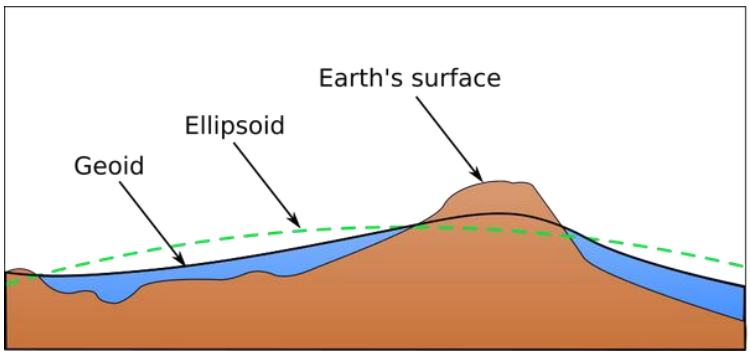


Figure 03: Ellipsoid and Geoid

4.2 The Ellipsoid

A regular mathematical surface. Local ellipsoids are used for national mapping; global ellipsoids for world systems.

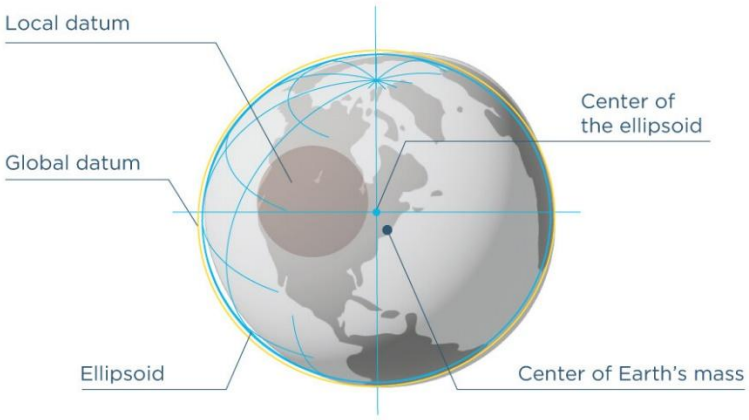


Figure 04: Local ellipsoids and the global ellipsoid

4.3 The Geoid

An equipotential surface of the Earth's gravity field, perpendicular to gravity direction, coinciding with mean sea level. It is used as the zero reference for altitudes.

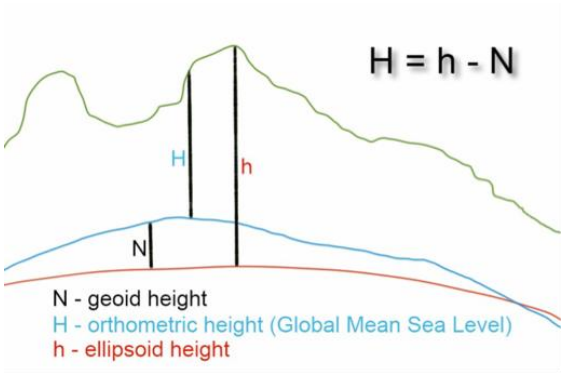


Figure 05: the geoid, reference for altitudes, Patrick SILLARD, 20004.

4. 4 Altitudes

A level surface is an equipotential surface perpendicular to verticals. The geoid is used as the reference surface for altitudes. Differences in gravity cause variations in spacing between level surfaces.

4.5 Classification of Projection Systems:

Projection systems establish correspondences between ellipsoid and map points, generating distortions in lengths, angles, and surfaces.

4.5.1 Classification of projection systems according to alterations

- Conformal projections: preserve angles but distort surfaces (e.g., Mercator).

- Equivalent projections: preserve areas but distort shapes (e.g., Eckert IV).

- Aphylactic projections: preserve neither but minimize distortions (e.g., equidistant projections).

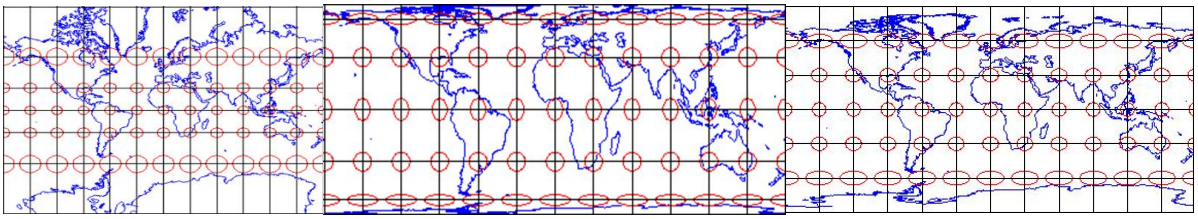


Figure 07: Conformal projections, Equivalent projections and Aphylactic projections

4.5.2 Classification by Construction Methods

- Azimuthal projections: projection onto a tangent plane (gnomonic, stereographic, orthographic).

- Cylindrical projections: tangent or secant cylinder (e.g., Mercator, UTM).

- Conic projections: tangent or secant cone, axis aligned with poles (e.g., Albers, Lambert).

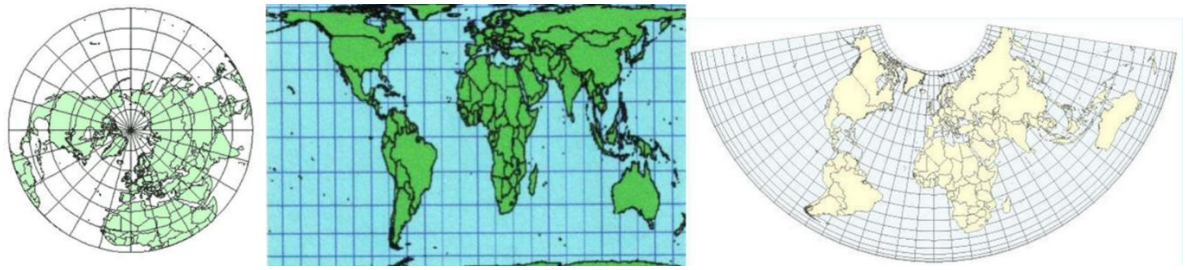


Figure 08: Azimuthal projections, Cylindrical projections and Conic projections

5. GENERAL LEVELING

The first leveling networks date back to the 19th century. Initially local and limited to large cities, they later became national for the construction of major projects such as roads and canals. This marked the beginning of the General Leveling of France (NGF).

Several networks followed:

• **The Bourdalouë network:** Created by Paul Adrien Bourdalouë, the zero level was established in 1860 in Marseille and served as the origin point (it was the fundamental point). Observations continued until 1864. No gravity values were taken into account in this network.

• **The Lallemand network:** Developed in 1884 based on an altitude origin, established after a tide gauge campaign from 1885 to 1897, this origin is 71 mm higher than that of "Bourdalouë".

• **The current IGN69 and IGN78 network (Corsica):** the aging Lallemand network has been partly re-observed and completely recalculated. The French leveling network, a legal reference network including the French Base Leveling (NBF) is made up of IGN 69 and IGN 78, a regulatory altitude system, materialized by more than 400,000 markers.

6. TOPOGRAPHICAL OBSERVATIONS:

In topography, observations generally apply to lengths of less than a few thousand meters. Within these limits, the topographic images of points S, A, B on the terrain (Figure 9) are the points s, a, b, orthogonal projections following rectilinear and parallel verticals on the horizontal plane, or topographic plane, of zero altitude; a point on the plane is therefore the unique image of all the points located on its vertical.

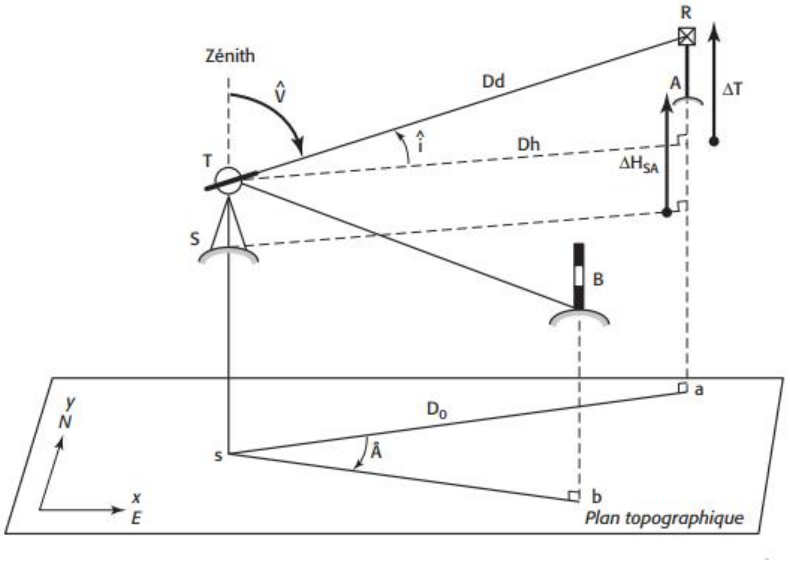


Figure 09 : Observations topographiques

Le positionnement des points s, a, b est assuré en planimétrie par leurs coordonnées rectangulaires E et N dans un système de projection et en altimétrie par leurs altitudes H dans les systèmes IGN69 ou IGN78. Pour un chantier isolé de faible étendue, le topographe peut aussi situer les points dans un repère orthonormé local x, y sommairement orienté par rapport au nord et choisir un plan de référence horizontal d'altitude arbitraire. Dans cet environnement simplifié, les observations topographiques sont classées en trois catégories.

6.1 Angles:

Angles are measured using a theodolite T positioned vertically above S, with all sightings of the same vertical plane having the same topographic image.

A distinction is made between:

• **the horizontal,** or azimuthal, angle Â of two sightings TR and TB, which is the angle of their topographic representations sa and sb, in other words the rectilinear angle of the dihedral of the vertical planes; the horizontal angle Â = (sa, sb) is measured clockwise on the horizontal circle of the theodolite;

• **the vertical angle of a sighting,** TR for example, is generally the zenith angle Ṽ, measured from 0 gon to 200 gon from the zenith of the station, measured on the vertical circle or eclimeter of the theodolite. The angle of inclination î is the angle of the sight with the horizontal: positive for an upward sight, negative for a downward sight, complementing the right angle of Ṽ.

The angle units are: radian (rad), grade (gon)

6.2 Distances:

- The direct distance Dd, or inclined, oblique, slope-dependent distance, etc., is the length of the straight line segment joining two points in space, a distance meter placed at T and a reflector at R, vertical to A, for example.

- The horizontal distance Dh at the altitude of T, the orthogonal projection of the direct distance Dd onto the horizontal plane of T, is generally the result of a reduction calculation of observations.

- The distance D0 reduced to the ellipsoid, differs from Dh when measurement accuracy requires taking into account the fact that the verticals are not parallel but converge at the center of the Earth; D0 is smaller than Dh for distances measured above the zero surface, and larger otherwise.

- The distance D reduced to the projection system, obtained by correcting D0 for the linear alteration of the system. The unit of measurement for distance is the meter, the length of the path traveled by light in a vacuum during a duration of 1/299,792,458 s.

6.3 Elevation Differences:

The elevation difference between two points S and A, for example, is the difference in altitudes of these two points; it is an algebraic value whose sign depends on the direction of trajectory:

ΔHSA = (HA – HS) = – (HS – HA).

7. ACCURACY OF OBSERVATIONS

Uncertainties are often gross and arise from inattention or oversight on the part of the operator; to detect errors, which are always likely to occur, inspections are performed.

Inspection is an operation involving assessments, observations, and/or calculations intended to detect the presence of errors.

A distinction is made between:

- Direct inspection, inspection by pure and simple repetition of the initial observations and/or calculations.
- Indirect control, control through observations and/or calculations different from those initially performed.

8. THE MAP

Cartography is the set of graphic techniques used from original surveys or various documents for the development and production of maps.
A regular map, resulting from a regular survey, has a graphic standard deviation of 0.1 mm in planimetry; after enlargement, the notion of a regular plane disappears.
The various tasks that result in the base map are, in chronological order:
• Geodesy
• Leveling
• Aerial photography, photographic coverage of France at approximately 1:30,000
• Restoration of the images providing the stereominute
• Complete topographical analysis of the stereominute
• Drafting of the base map
• Drafting of the derived maps
• Reproductions and prints.

Given the scale, details are represented in the form of conventional symbols; Cartographic writing is done in four colors:
– black for planimetry;
– blue for hydrography, i.e., the representation of water;
– orange for roads and orography, the cartographic expression of relief that derives from the laws of geomorphology, which describes and explains it;
– green for vegetation.

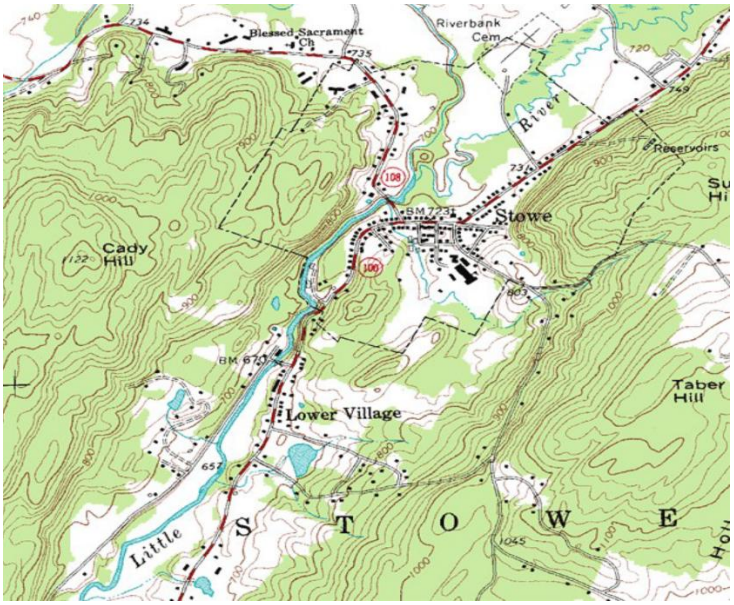


Figure 10 : topographic Carte