# DETERMINATION OF ROTATIONAL FAULT PLANE*

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Abstract

By the use of stereographic projection, the inclination of the fault plane may be easily determined. There are two cases in this problem: 1. Knowing the strikes and dips of the bedding planes and the strike of the fault plane, one can find the dip of the fault plane; and 2. knowing the strikes and dips as well as the pitches and plunges of the linear structures of the bedding planes, one can find the strike and dip of the fault plane. Several examples from the geological maps of dam works prove that there are only 2° or 3° differences between the measured and constructed values.

Fault is a general phenomenon and may be easily observed in the field by geologists. It is usually assigned to happen on account of the fault breccia and slickensides as well as the abrupt discontinuity of the strikes of the beds, or sometimes the duplication of the strata in connection with the geological structures. But the accurate determination of the plane of the fault may not be easily done especially in the large geological areas, so the strike and the dip of the fault plane are represented only diagramatically in the geological maps. As the fault plane is quite important to dam work, underground water surveying, mining geology, etc., it seems to need a further statement about it.

The nomenclature of the fault is much complicated due to the different processes of formation, but as to the geometric relation with respect to the strike of the beds, it may be classified into strike fault, dip fault, and oblique fault. The last of these faults may be more often met with than the first two, which occur only under some particular conditions. As to the displacement of beds, a rotational movement will be more general than the parallel displacement along the strike, along the dip, or along both of the two. The rotational fault may be assigned as the normal type of fault, while others special ones.

When a fault happens, the plane of slipping is commonly a flat surface in order to facilitate the mutual movement of the beds on both sides of the fault, for the beds traverse along the shortest line, that is, along the more economic way than on the fluctuating surfaces.

In a rotational fault, the beds on both sides of it are twisted about the normal of the plane of the fault; the farther they are from the axis, the

*Parts of the contents were published in Chinese in *Acta Geologica Sinica*, Vol. XXXII, No. 4, pp. 354—359, 1953.

greater the displacement of the beds will be. The normal of the fault plane acts as a hinge so that if the forward end falls down, the backward end will be up thrown as shown in Fig. 1. A rotational fault in the geological map may be easily ascertained by the unlikeness of either strikes or dips, or both of the two beds, as shown in Fig. 2. The solving of the fault problems by

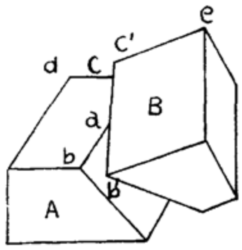


Fig. 1.

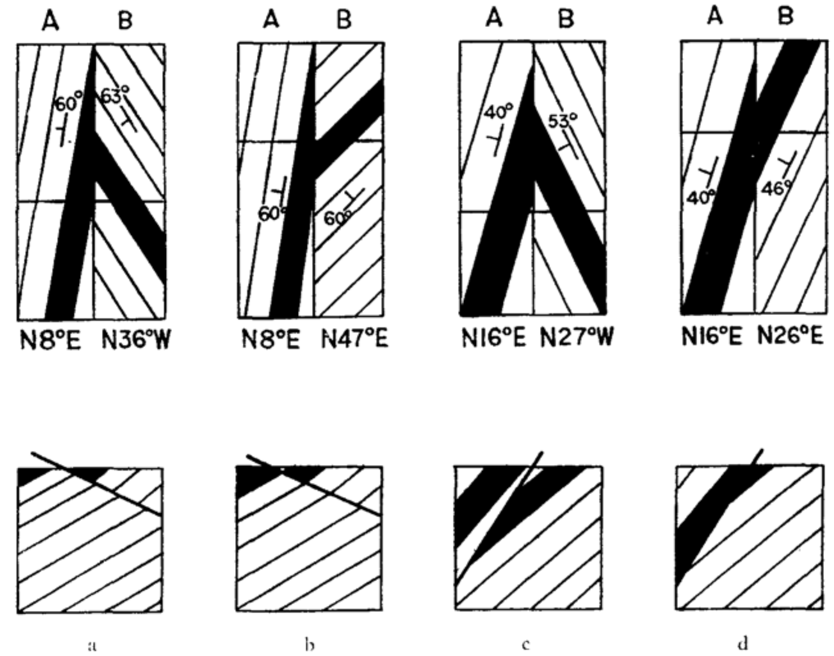


Fig. 2.

the use of stereographic projection has been extensively stated by Nevin in his book *Principles of Structural Geology*, fourth edition (1950), but it seems that the method here used has not been mentioned.

The angle of displacement of a rotational fault will be clearly shown by the normals of the beds. They should lie on a cone, whose axis is the normal of the plane of the fault and whose trace on the sphere is the circle *BCD* as shown in Fig. 3. The stereographic projection of *BCD* is also a small circle. The fundamental principle of it needs further statement in order to explain the method of the construction. Fig. 4 is a section through $P'AP$ of Fig. 3. $LM$ is the base, and $PA$, the axis of the cone. $GH$ is the projection of $LM$, and it is also a circle, which is proved as follows.

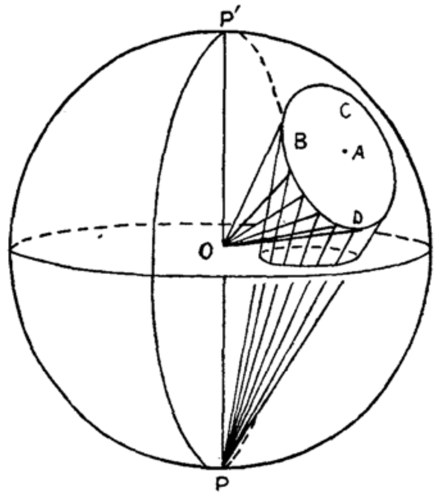


Fig. 3.

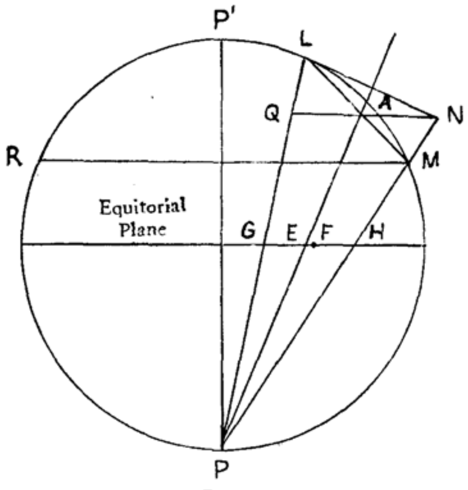


Fig. 4.

Draw $LN$ perpendicular to $PA$ and intersecting $PM$ produced at $N$. $LN$ is an elliptical base of the cone $LPN$. Take $LQ = MN$ and draw $QN$, which is a conjugate section with $LM$. $LM = QN$.

Draw $MR$ parallel to the equitorial plane. For

$$\frown{PM} = \frown{PR},$$

therefore
$$\angle RMP = \angle PLM$$
$$= \angle PNQ.$$

Therefore $QN$ is parallel to $MR$, and also to the equitorial plane. Then $GH$ must be also a circular section, which is the stereographic projection of $LM$. $E$ is the stereographic projection of the axis $A$. The normals of the beds have to fall then upon the small circle, whose centre $F$ is the middle point of the line $GH$. If the centre is found, the diameter $GH$ will be determined, and the normal of the plane of the fault will be known. There are two cases in this problem: 1. Knowing the strikes and the dips of the beds on both sides of the fault and the strike of the fault plane, one can find the dip of the fault plane. 2. Knowing the strikes and dips as well as the pitches and plunges of the linear structures of the beds, one can find the strike and the dip of the fault plane.

(1)

In Fig. 5. $GH$ is the strike of the fault plane in NS; $CD$ is the strike of

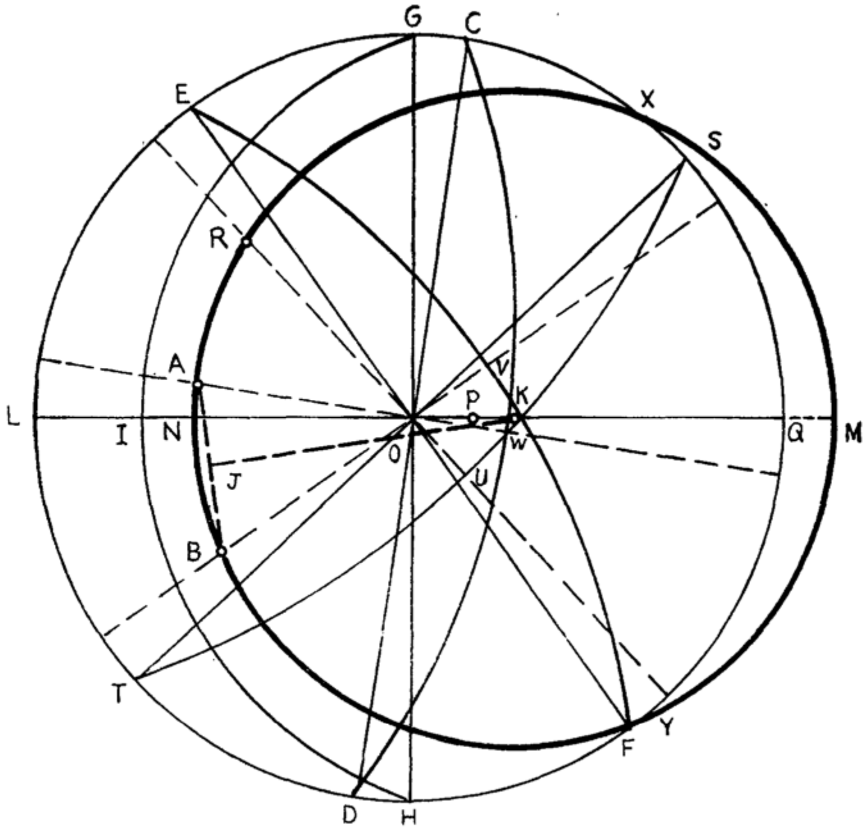


Fig. 5.

the unrotated bed in N 8° E that dips to 60°W; *CODW* is the bedding plane, whose pole is *A*; *EF* is the strike of the rotated bed in N 36°W that dips to 63°W; *EOFV* is the bedding plane, whose pole is *B*.

*A* and *B* as stated above must be on a small circle, whose centre has to lie on the line *JK* drawn perpendicularly from the middle point of *AB*. Meanwhile the centre of the circle must be also on the trace *LQ*, which is perpendicular to the strike *GH*. Therefore the intersection *K* of *JK* and *LQ* must be the centre of the circle.

Draw a circle *AMBN* with *AK* as radius and *K* as centre, then the magnitude of the circle is measured on the projection to be *MN*, which is about 157°, and the axis of rotation will be projected at the point *P*, which is 78.5° apart from either *M* or *N*. *P* is dipping to 19°E, which is the dip angle of the fault plane *GOHI*. *B* has been rotated counterclockwise around the axis *P* for an angle about 37°, which is the included angle between two great circles *PA* and *PB* (not shown in the figure). The geological map and section are represented in Fig. 2a.

If the faulted beds are rotated clockwise to *SOTU*, whose pole is *R*, the displacement of the beds in geological map is shown in Fig. 2b.

*AMBN* in this construction crosses the perimeter of the projection at *X* and *Y*, which represent the poles of the bedding planes in the vertical position, while the poles within *XMY* will represent the beds which are overturned. In this construction it seems possible that beds of unlike dip angles might appear in the same strike. The beds, whose poles emerge within *XAY*, are normal, and those within *XMY* overturned.

The fault plane as stated above dips, in general, toward the opposite directions of the bedding planes.

Fig. 6 shows that the fault plane dips to the same direction of the bedding planes. *GH* is the strike of the fault plane in NS. *CODW* is the unrotated bed, whose strike is N 16°E, and dip 40°W. *A* is the pole. *EOFV* is the rotated bed, whose strike is N 27°W, and dip 53°W. *B* is the pole.

By the same method of construction draw *AB*, and at the middle point *J* draw *JK* to intersect the line *LQ*. *K* is the centre of the circle *AMBN*, whose diameter *MN* is measured to be 49°. 24.5° is therefore its radius. *P* is the rotational axis or the normal of the fault plane; it dips to 61°W. *A* is rotated 99° clockwise to *B* about the axis *P*, that is the included angle of the two great circles *PA* and *PB* (not shown in the figure). The geological map is shown in Fig. 2c.

If *A* rotates counterclockwise to *R*, *SOTU* is the bedding plane. The geological map is shown in Fig. 2d.

The small circle falls within the primitive circle of the projection, and the fault is inclined generally to the same side of the beds. Two tangents

$OX$ and $OY$ may be drawn from the centre of the projection, and they include the greatest angle between the strikes of the beds on both sides of the fault. The small circle at times may be also larger, so that it crosses the perimeter as in Fig. 5.

From the two constructions (Figs. 5 and 6), we see that there is no intersecting point. $K$ can be found when the bisector $JK$ is parallel to or coinsides with $LQ$. If these cases, though very rare, are met with, the next method may give valuable reference for finding the intersection $K$.

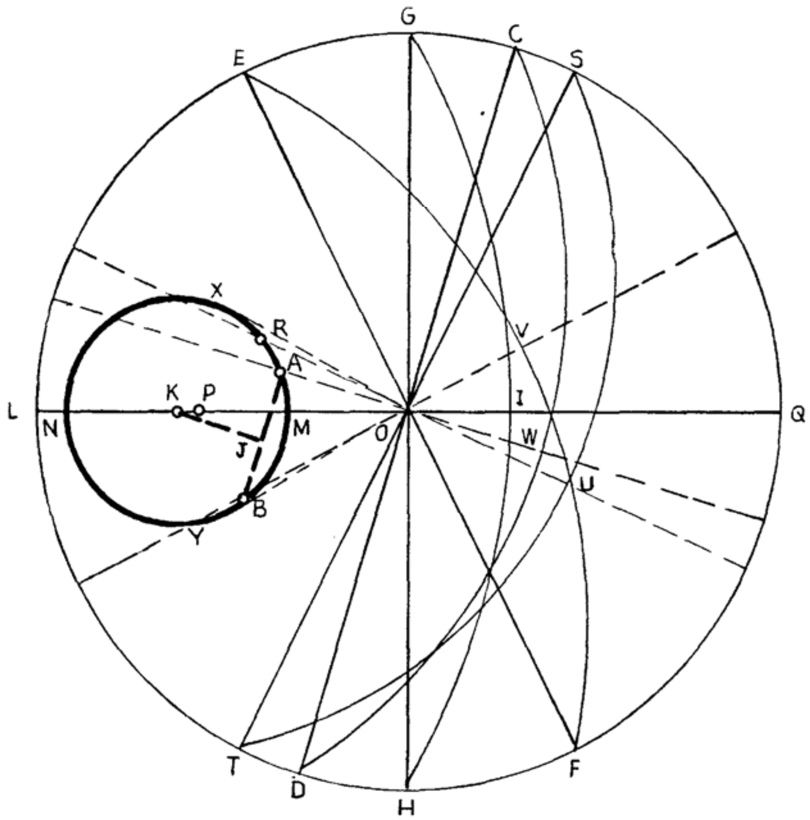


Fig. 6.

(2)

As a matter of fact, the plane of a fault cannot be generally observed due to the alluvial deposits, tallus deposits, river deposits, etc. The only basis for the determination of a fault can be deduced by the changes of strikes of beds on both sides of a fault. If no fault plane is visible, then $LQ$ cannot be drawn and the intersection $K$ cannot be found. But this difficulty may be easily overcome by measuring some natural linear structures on the bedding planes. In sedimentary rocks, they are usually represented by some deposition layers, torrential beddings, ripple marks, parallel arrangement of pebbles or columnar minerals, etc.; in metamorphic rocks, schistosities, Augen structures, lenticular textures, linear directions of minerals, etc.; and in igneous rocks by vesicular structures, flow directions, xenolithic inclusions, etc. Moreover, the structures produced by the predynamic movement, such as joint planes, drag folds, striations, etc. are also best references. The petrofabric analysis may be sometimes taken in addition as a method for the determination of preferred orientation. After faulting, the same linear structures are rotated by the same angle as the normal of the beds. The loci of the linear structures are therefore also concentric circles. In Fig. 7, *OM*

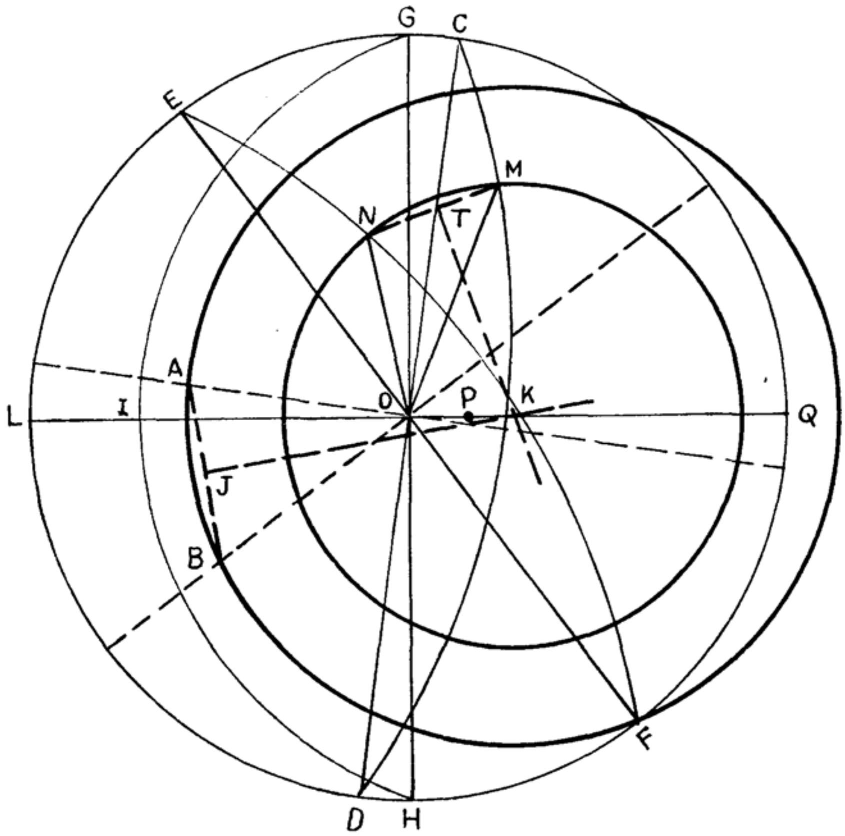


Fig. 7.

represents a linear structure before faulting, whose pitch is *COM*, and plunge, $(90° - OM)$, and after faulting, *ON* represents the linear structure, whose pitch is *EON*, and plunge, $(90° - ON)$. It is plain that the angle included between the two great circles *PM* and *PN* is just equal to that between the great circles *PA* and *PB*. The centre *K* must be the intersection of both bisectors *JK* and *TK*. In order to make the determination more accurate, all the visible linear structures should be measured, so that several concentric circles are drawn. The average value of intersections may be assigned to the centre $K$ of the circle. The normal of the fault plane is then determined.

After the strike and the dip of the fault plane is determined, the next process is to find the passage of the fault line in the field or in the map. As Fig. 1 shows that point $a$ acts as a hinge of both blocks, therefore beds will not be displaced there. The fault line should pass through the hinge point, which may be fixed in the field by the point of connection of the same beds, or in geological map by extrapolation of the strikes of the same beds to the hinge point. The accompanying parallel movements, if they happen, cause only an alteration of the hinge point, and do not change the rotational angle.

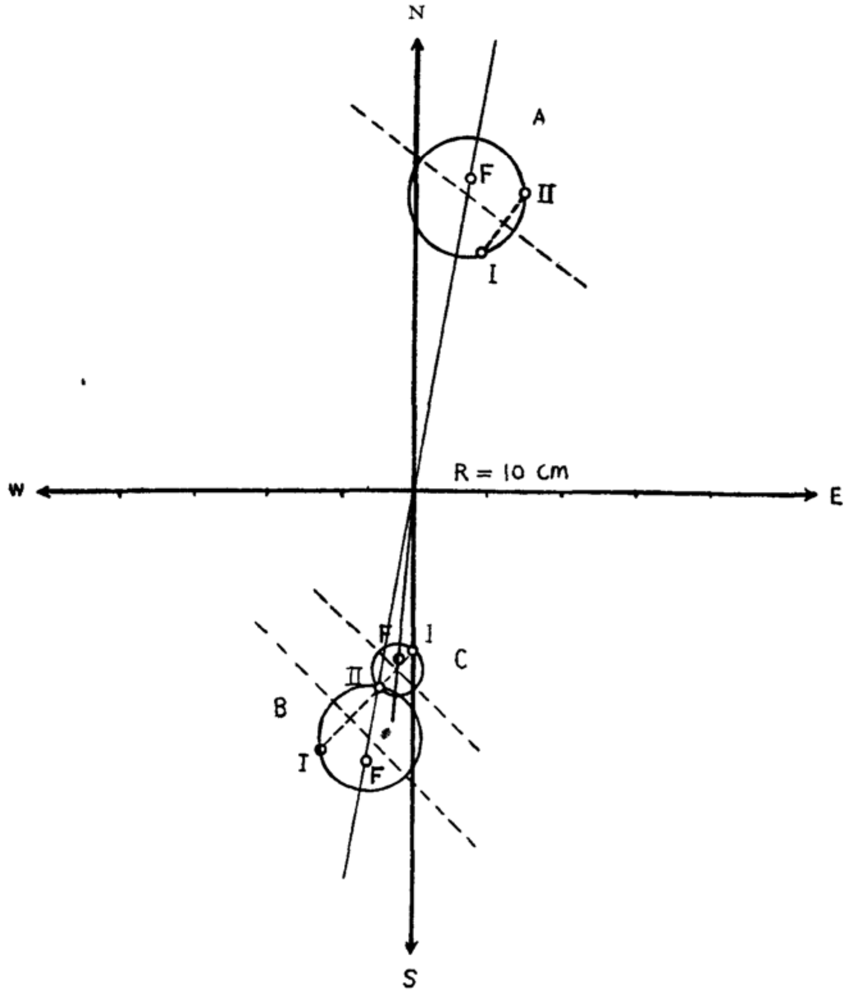


Fig. 8.

Some examples in the dam work of the Ministry of Geology show that the measured strike and dip of the fault plane are generally in agreement with those by construction. Fig. 8 shows three examples *A, B* and *C* drawn together in a stereographic projection. The strikes and dips of the fault planes measured in the field are represented by I, II and *F* respectively. Each normal of the fault plane falls within a small circle. The differences between the measured angles and the constructed values are not more than 2° or 3° as shown in Table 1.

**Table 1**

| Measured | | Constructed | Figures |
|---|---|---|---|
| Beds | Fault plane | Fault plane | |
| *I.* Strike N75°W<br>Dip NE 36°<br>*II.* Strike N70°W<br>Dip NE 45° | *F.* Strike N80°W<br>Dip NE 45° | Strike N80°W<br>Dip NE 43° | 8.*A* |
| *I.* Strike N70°W<br>Dip SW 40°<br>*II.* Strike N80°W<br>Dip SW 30° | *F.* Strike N80°W<br>Dip SW35—45°<br>(average SW 40°) | Strike N80°W<br>Dip SW 38° | 8.*B* |
| *I.* Strike EW<br>Dip SW 24°<br>*II.* Strike N75—85°W<br>(average N80°W)<br>Dip SW 30° | *F.* Strike N85°W<br>Dip SW 25° | Strike N85°W<br>Dip SW 22° | 8.*C* |

In conclusion, the use of the stereographic projection in solving the rotational fault is much helpful to the mining engineers and geologists. The linear structures of the bedding planes should not be neglected during field work.