SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 740 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 72 NR 2

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A ROCK SAMPLE ORIENTATION SYSTEM USED BY THE GEOLOGICAL SURVEY OF SWEDEN

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ABSTRACT

Henkel, H., and Nisca, D.: A rock sample orientation system used by the Geological Survey of Sweden. Manuscript received 15th Nov., 1977.

The field and laboratory apparatus for orientation of hammer cut or motor cut rock samples are briefly described. The field apparatus consists of a tripod having hollow marking-legs and a sun compass mounted. In the laboratory the sample can be replaced into the tripod reference system which in turn can be related to the laboratory reference system using a perspex cube with inserted tripod. The final calculation to the geographical reference system is accomplished by a computer. The sun compass will be described in detail. For details about the mathematical concepts etc. the reader is referred to an internal report about the rock sample orientation system (Henkel and Nisca 1977).

HISTORICAL NOTES

Since 1966 orientated rock samples have been collected in a systematical way in combination with geological mapping in Norrbotten in Northern Sweden. Lars Granar constructed the laboratory measurement system (which is documented in Henkel and Mannby 1976), in which the sample fixed into a perspex cube is positioned between two pairs of flux gate probes to measure its magnetical properties. Gideon Hellsten (1966) constructed a field orientation device which also made the fixation for measurement easier. In 1974 a sun compass was constructed by the authors and added to the field orientation device. Today orientated samples are taken mainly on magnetic rocks in order to estimate their remanent magnetization NRM. Another field in which the orientation apparatus could be used is for fabric analysis either magnetically (susceptibility anisotropy) or mineralogically. In another report (Henkel and Søndergaard 1978) the mathematical treatment of laboratory measurement and the data handling facilities will be documented.

THE FIELD APPARATUS FOR ROCK SAMPLE ORIENTATION

A plastic tripod incorporating a spirit level, Fig. 1, is fitted against the sample while in place on the rock outcrop. Its relations to geographical coordinates can be determined fairly well by measurement of the strike and the dip of the tripod plane (see also Fig. 5). The legs of the tripod are hollow in order to make accurate markings with a pen on the surface of the rock sample. These markings are then used in the laboratory to re-orientate the sample into its original position. The distance between the centres of the legs is 42 mm. The rock samples are cut out from the rock using a hammer or a rotating carborundum disc. The latter method is especially useful where flat outcrops are sampled.

The measurement of the strike and dip of the orientation tripod can be made by using a magnetic compass having a clinometer and 360 degrees division. For weakly magnetized rocks this gives an estimation within 1 or 2 degrees of the strike and dip of the tripod plane. For rocks with stronger magnetization additional measurements must be made to estimate the local (near sample) and the regional deviation from magnetic north in order to obtain the true geomagnetic north direction. During this measurement the compass centre is held in the same position as during the measurement of the tripod strike. There is a large variety of methods to perform these magnetic declination measurements. Fig. 2 shows a method where a tape is laid over a dyke outcrop in unmagnetic surroundings and the declination at each sampling location is then estimated from the measurement of the tape strike at this location. An example in Fig. 3 shows the importance of making proper measurements of the local magnetic deviation as these may be rather large and change sign across a single dyke. A common method of measuring the magnetic deviation is to compare a known direction, for instance towards a building or a topographic feature, with the corresponding angle on a map.

THE FIELD APPARATUS COMBINED WITH A SUN COMPASS

When a sun compass can be used, the magnetic influences are eliminated. A sun orientation equipment has been adapted to the orientation tripod as shown in Fig. 4. The orientation of a rock sample is accomplished by levelling that side of plate A which is parallel to the arrow (direction +A) and in the next step to level plate B. The shadow thrown on plate B by the pin (inserted into plate B) is now read off its scale, Fig. 5. The angle between plate A and plate B is read from the dip scale of plate C. In using a separate inclination scale, the accuracy of this measurement is increased slightly as compared to the measurement with the clinometer of a magnetic compass. The entire device can be folded to a package not larger than a conventional magnetic compass.

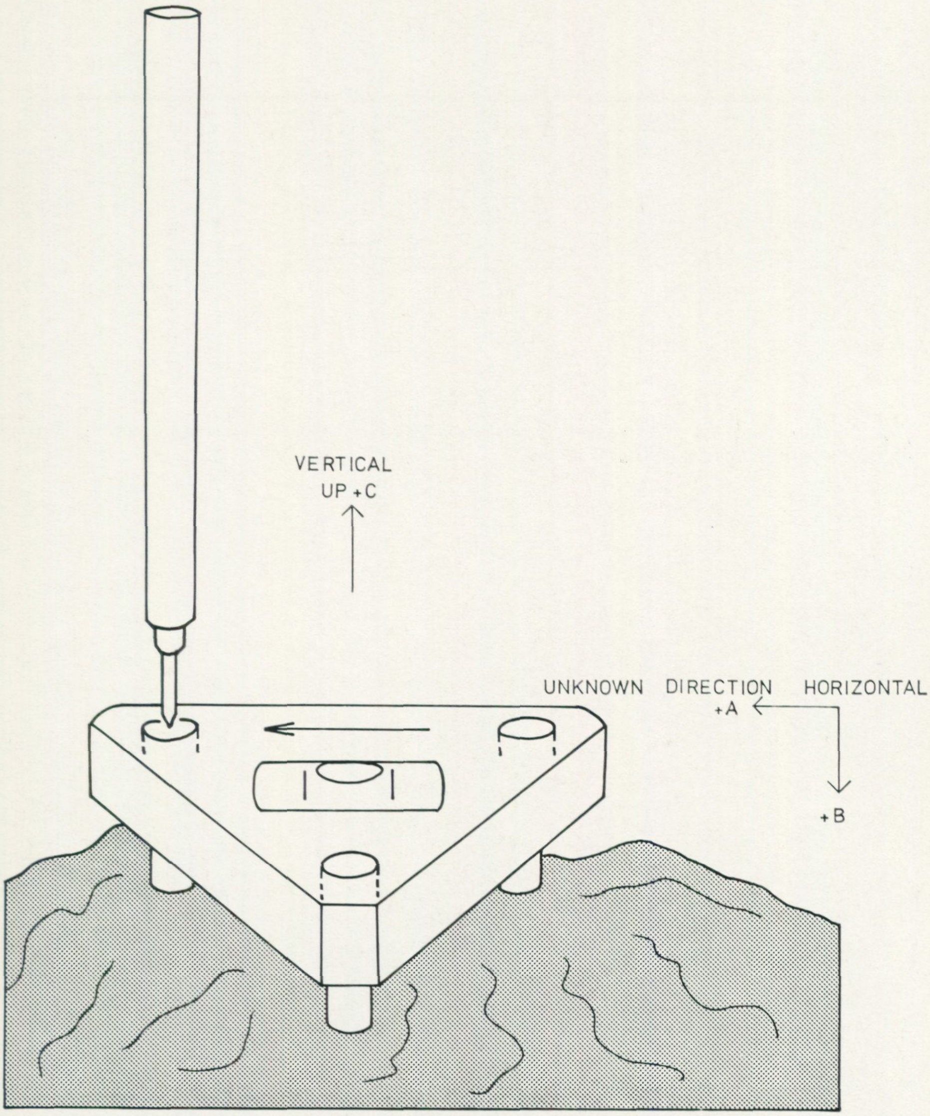

Fig. 1. Field orientation tripod and definition of the coordinates measured. Strike (the angle between the tripod arrow and the geographical north in the horizontal plane). Dip (the angle between the horizontal plane and the tripod plane).

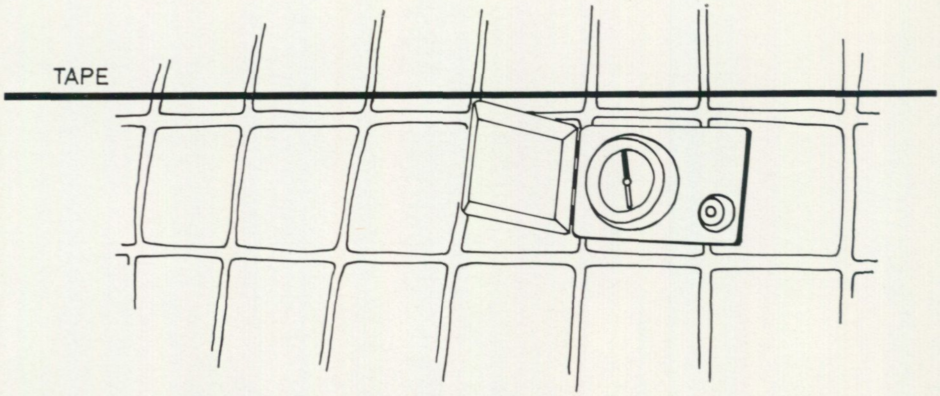

Fig. 2. Measurement of local magnetic deviation using a tape as reference. Samples have been cut using a rotating carborundum disc.

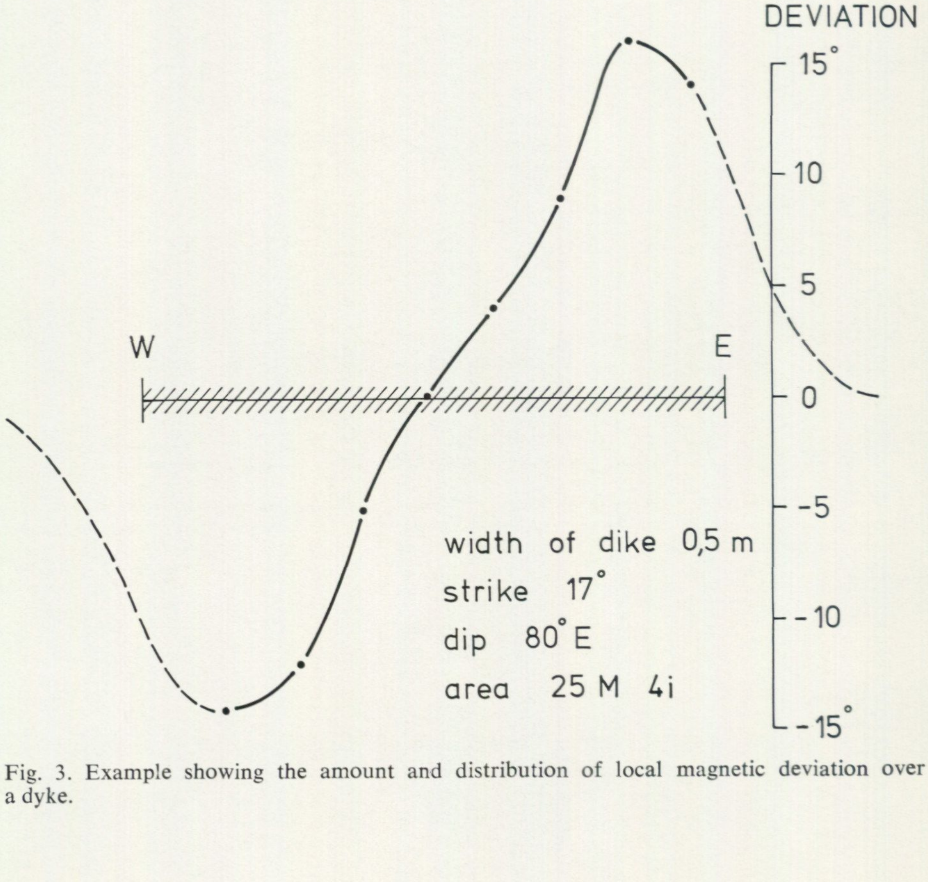

Fig. 3. Example showing the amount and distribution of local magnetic deviation over a dyke.

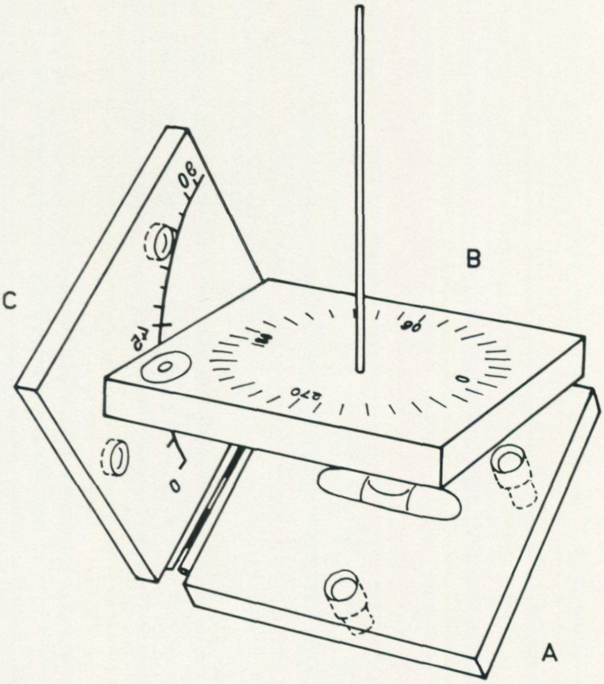

Fig. 4. Sun compass combined with orientation tripod.

For calculation of the sun azimuth at an observing point the following variables must be known: latitude or declination (D) of the sun, local hour angle (LHA), latitude (L) and longitude of the observing point, time and date. The sun's declination varies from about +24 degrees to −24 degrees during a year, but is the same from year to year. The local hour angle is also almost the same from year to year, but it is altered in a non linear way during a year. This deviation is expressed by the quantity Equation of time. The declination is found directly in an ephemeris or an astronomical almanac (Ephemeris 1973). The local hour angle is obtained by adding the east longitude or subtracting the west longitude of the observing point to the Greenwich hour angle (which is also found in an ephemeris). By using spherical trigonometry the sun azimuth γ is obtained (Creer and Sanver 1967, Henkel and Nisca 1977) according to the formula:

$$\tan\gamma = \mathrm{sinLHA} \Big/ (\mathrm{tanD\ cosL} - \mathrm{sinL\ cosLHA}) \qquad (1)$$

The signs of LHA, D and L determine in which quadrant γ lies, as the numerator and the denominator in equation 1 can both be positive and negative.

$$\gamma = \pm\, v + n \cdot 180$$

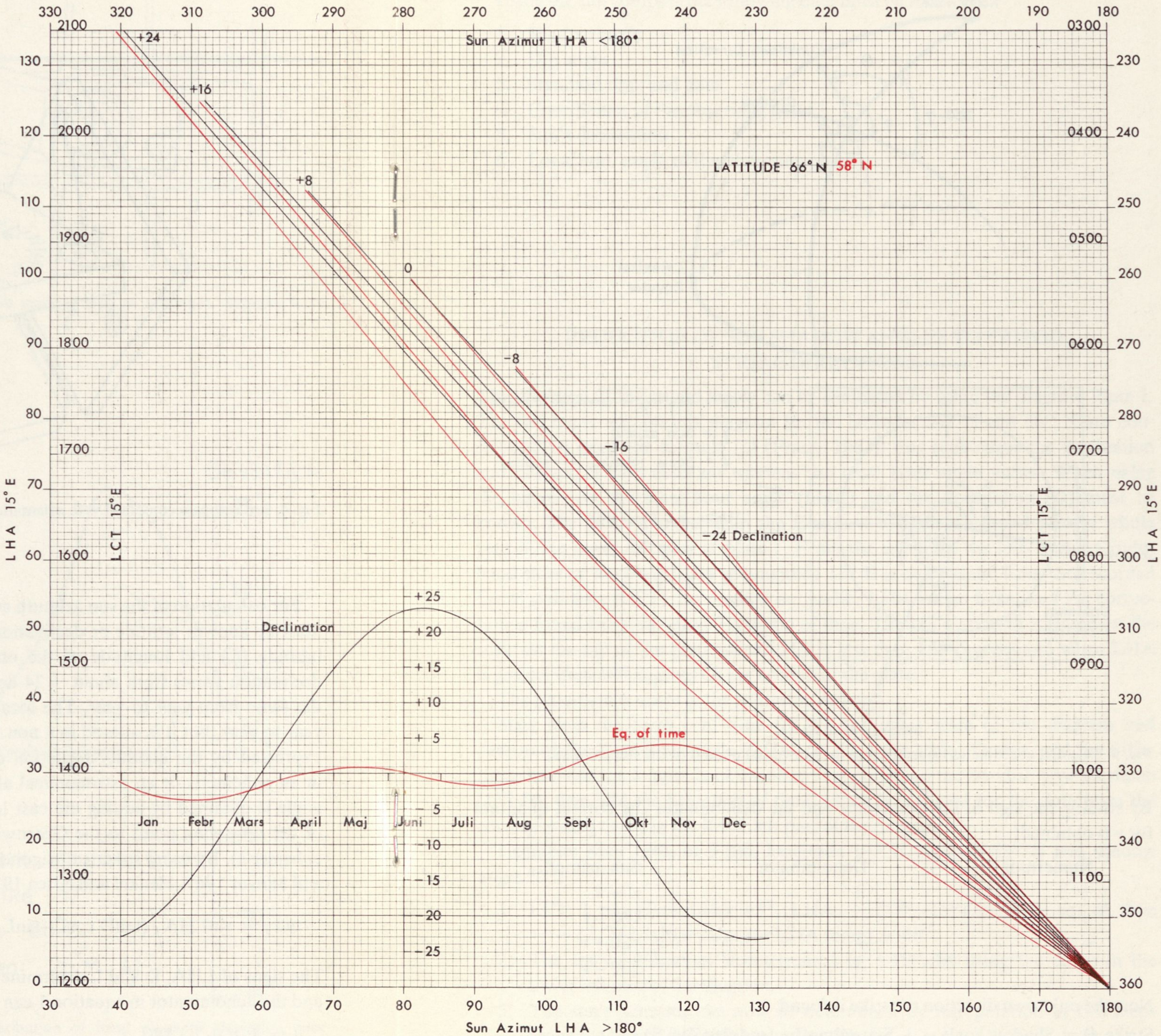

PLATE 1. Diagram to be used when evaluating the direction of the tripod arrow.

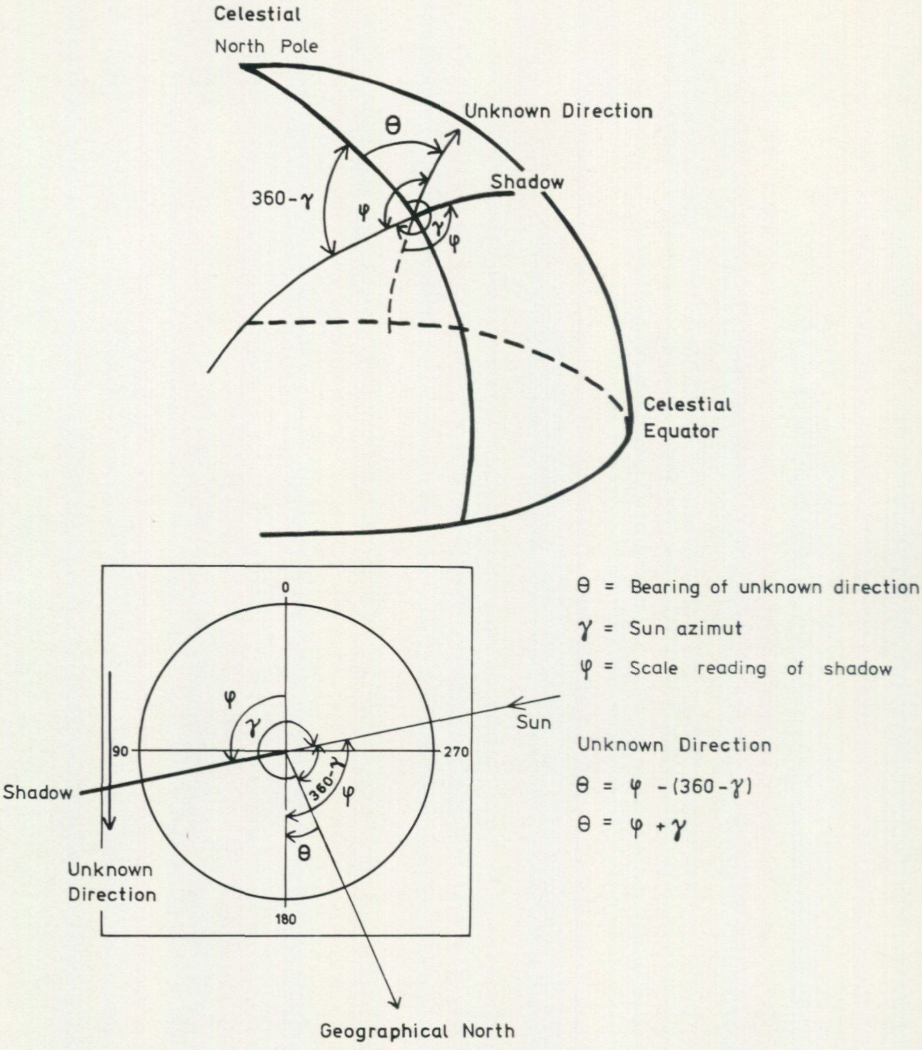

Fig. 5. Celestial coordinates transferred to the horizontal plate B of the sun compass.

By studing the sign of the numerator and the denominator the correct quadrant for γ is obtained:

Numerator	Denominator	Sun azimuth
+	+	$\gamma = v$
+	−	$180 - v$
−	−	$180 + v$
−	+	$360 - v$

Now the unknown direction or strike is found.

Strike Θ = Shadow angle φ + Sun azimuth γ (see also Fig. 5).

Using the sun compass the following data must be recorded:

1. Shadow angle
2. Dip angle
3. Standard time and date
4. Coordinates of the observing point
5. Sun's declination
6. Local hour angle of the observing point

REDUCTION OF SUN SHADOW ANGLES TO TRIPOD STRIKE DIRECTIONS

The direction of the tripod arrow can be evaluated by using the diagram Plate 1. The two curve sets on this diagram for the latitudes 58° N and 66° N are constructed by using the formula (1) (Fraser 1963). For each curve the declination and latitude is held constant whereas the local hour angle varies. When using the curve sets the local hour angle (LHA) and the declination (D) must be known. The latter together with the Equation of time are found for the whole year in the lower left part of plate 1. From the scales on the left- and the right-hand sides of the plate LHA at longitude 15° E is determined from the recorded Local civil time (LCT). As pointed out earlier LHA is non linear and the correction is found from the curve Equation of time. The sun's azimuth is found on the scale on the top of the plate when LHA is less than 180 degrees and when LHA is greater than 180 degrees on the bottom of the plate.

The reduction is made in the following order:

Start from the local civil time (LCT), the inner scale of the diagram and determine the local hour angle (LHA) on the outer scale. To this, add the difference between the longitude of the observing point and the Swedish time meridian (15° E), then add the Equation of time, which is obtained for the date from the corresponding curve in the lower left part of the diagram.

Example: May 16th, at 3 pm, longitude 17° E, latitude 62° N and shadow angle 50°.

1. LCT 3 pm gives LHA 45°, LHA + (17°–15°) = 47°, eq. of time = +1°. The initial value for LHA (corr) = 48°.
2. The sun's declination is determined to +19°, by using the curve in the lower left part of the diagram.
3. The sun's azimuth can now be determined by interpolation in two steps along the line of the initial value, see Fig. 6.

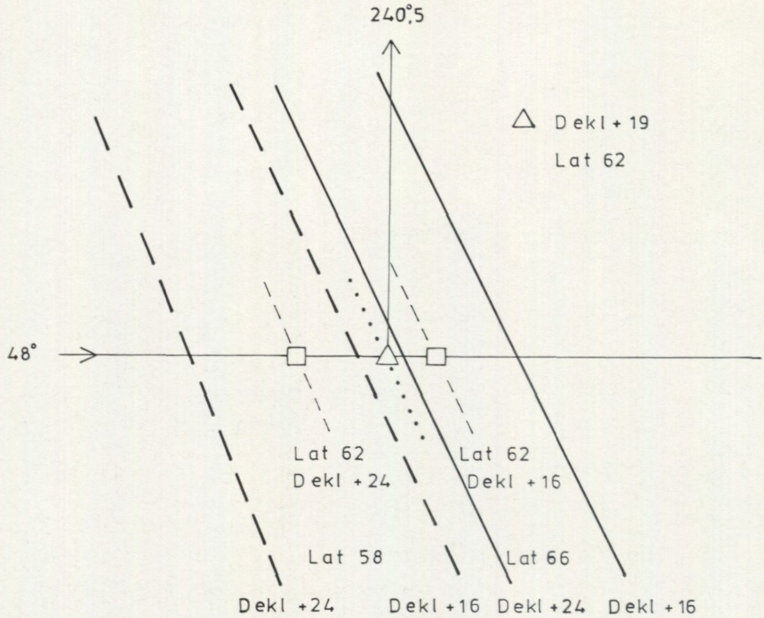

Fig. 6. Interpolation of latitude and declination in Plate 1.

In the first step, use the curves marked declination $+24°$, latitude 58° and declination $+16°$, latitude 66° respectively. Let the declination be fixed, interpolate for the desired latitude 62° (58 to 66 degrees, red and black curves respectively). The squares in Fig. 6 correspond to latitude 62°, declination $+24°$ and latitude 62°, declination $+16°$ respectively.

In the next step the desired declination $+19°$ is interpolated between the previously determined positions of the latitude. The sun's azimuth is determined at the top of the diagram when LHA $< 180°$ and at the bottom when LHA $> 180°$. In this example, read at the top 240°.5.

4. The tripod direction is the sum of the sun's azimuth and the shadow angle, $240°.5 + 50° = 290°.5$. When values larger than 360° are obtained, subtract 360°.
5. Readings and interpolations should be done with an accuracy of about 0.5 degrees which gives an error less than one degree in the determined direction. The mean error in the whole orientation procedure can be approximated to about ± 1.5 degrees (Henkel and Nisca 1977).

Additional unfolded plates can on request be obtained from the Geological Survey of Sweden Regional Geophysics Section.

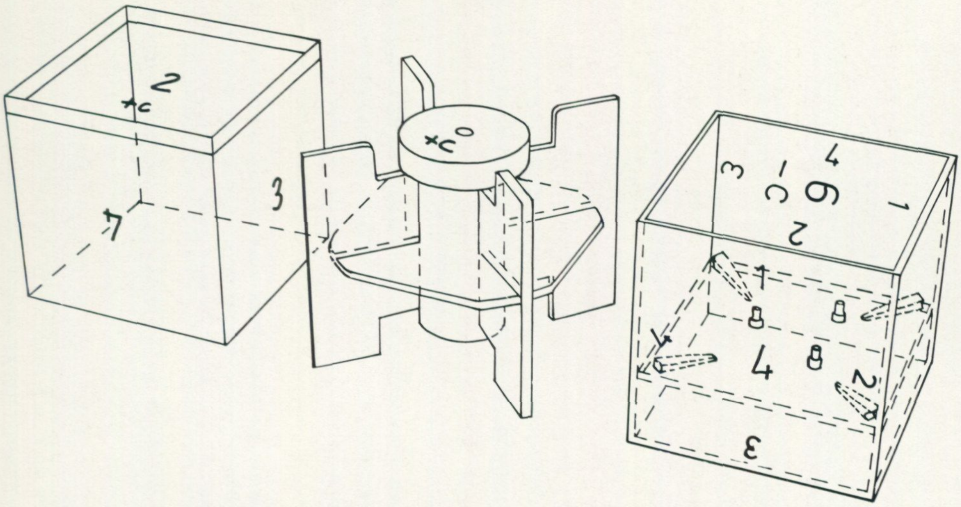

Fig. 7. Laboratory orientation apparatus: from left to right for unorientated samples, drill cores and orientated samples respectively.

THE LABORATORY APPARATUS FOR ORIENTATION OF ROCK SAMPLES FOR THE MEASUREMENT OF MAGNETIC PROPERTIES

In the laboratory the orientated rock samples are placed and secured on a tripod similar to that in the field, by using the markings of the position of the tripod legs. Here the tripod is mounted on a perspex cube as shown in Fig. 7. This cube has 120 mm sides. The walls of the box are parallel to the strike and dip of the tripod plane (Fig. 1). The box fits into a firm holder that also contains 4 flux-gate probes arranged in a plane parallel to the local geomagnetic field (the laboratory reference system), Fig. 8.

The measured magnetic components obtained for 24 positions of the measuring cube containing the sample are automatically punched on tape and then converted into rock magnetic properties in the data system SURE (Larkin 1976). Firstly the strike is calculated for samples which are orientated by the sun compass then the magnetic susceptibility (as a scalar or tensor) and the remanent magnetization (as a vector) are computed and listed. In a second step the petrophysical properties are grouped for rock types and displayed on a variety of diagrams, such as: density-susceptibility and susceptibility-q-value including 2-dimensional frequency distributions, maps of density, susceptibility or q-values, lower hemisphere plots of vectors including areal frequencies, etc.

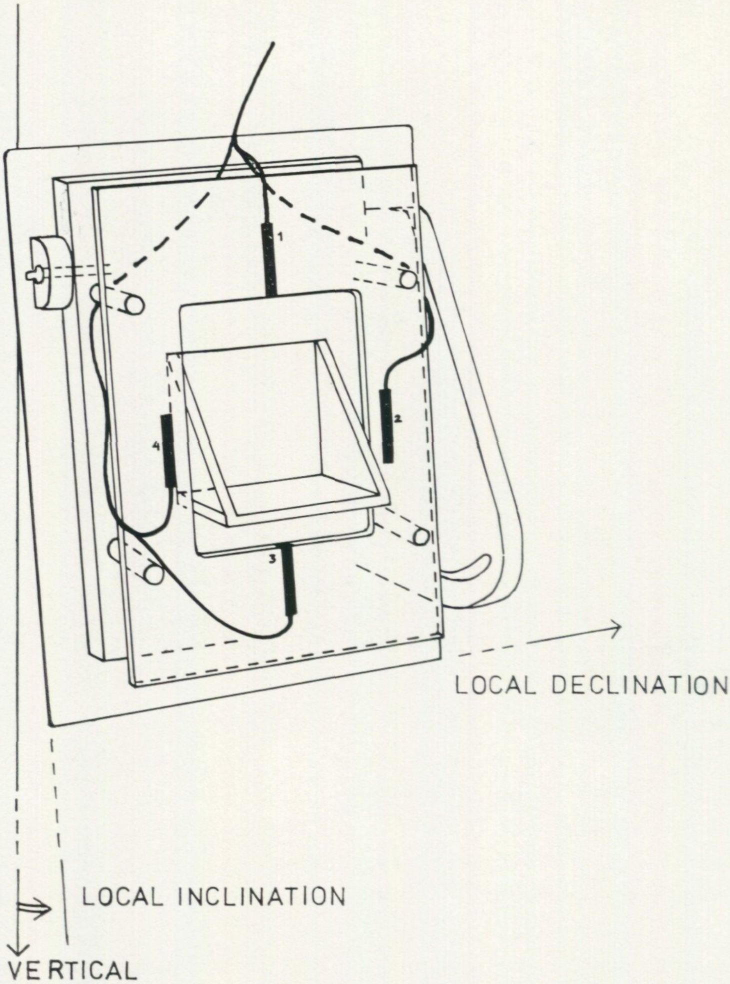

Fig. 8. Measurement apparatus and its orientation parallel to the local geomagnetic field. 1 – 4 denote flux gate probes.

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