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Orientation errors in paleomagnetic sampling and their effects

Masaru Kono[1*]

[1]Tokyo Institute of Technology

In paleomagnetic studies, samples often have shapes of cylindrical cores which are obtained by engine drills. In this case, two angles measured in the field (plunge of cylindrical axis from horizontal plane, and the angle between a horizontal direction in the core and the true north) will enable the transformation of direction of magnetic remanence to geographic coordinates. It is not difficult to perform the angle measurements with an error of about 1 degree or less. The angular error in paleomagnetic directions are measured by Fisher's semi-angle of 95% confidence, which is typically a few to ten degrees. It appears therefore that the orientation errors are negligibly small.

However, this it not quite correct. There is no problem about the measurement of plunge, but the angle in the horizontal plane is often measured by a magnetic compass, which can be source of large errors. In particular, volcanic rocks often carry strong magnetization which can cause a large local magnetic anomalies. This was known for a long time, but the absence of relevant data prohibited quantitative estimate of orientation errors.

We have obtained quite a large number of data (182 lavas, 903 samples) from Lundarhals area of Iceland. Among them, more than 200 samples have data of three independent horizontal angles; one by sun's direction, the second by reference to some reference point, and magnetic azimuth. Among the rest, more than 600 samples have reference and magnetic azimuths. Only 30 samples are determined by magnetic azimuth alone. From a detailed analysis of these data, the following conclusions were obtained.

(1) The difference between sun and reference azimuths are 0.0 +- 0.6 degrees (the mean and standard deviation, for n=203). This is small enough and can be ignored compared to other errors. Consequently, if either of these angles are available, we have almost error-free data.

(2) The differences between the sun and magnetic azimuths are 0.5 +- 7.8 degrees (n=240), and those between the reference and magnetic azimuths are 0.0 +- 6.9 degrees (n=844). This error is not negligible in the paleosecular variation studies, in which the typical ASD is of the order of 10 to 20 degrees.

(3) In general, samples from the same lava show similar errors. Thus it appears that the main reason for the error is the magnetization of the lavas itself. However, it is hard to find a good correlation between the direction of magnetization and the orientation errors.

Keywords: paleomagnetism, volcanic rocks, orientation error, paleosecular variation