A PALAEOMAGNETIC STUDY OF THE DE BEERS DIAMOND MINE

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Sampling

A technique has been devised which enables the collection of accurately oriented block samples for palaeomagnetic research from deep underground without recourse to magnetic methods, but utilizing the mine survey pegs. Twenty two such blocks have been collected from the De Beers Mine comprising fourteen samples of kimberlite (three being unusable), five samples of Precambrian Ventersdorp lava from the immediate contact with the kimberlite, two accidental inclusions of Ventersdorp lava and a sample of Ventersdorp lava well away from the contact with the kimberlite pipe. All of these samples were taken from the 585 and 595 m levels.

In addition results from five kimberlite samples collected in an earlier pilot study at higher levels have been included in the analysis. These samples were oriented by means of a Brunton compass

Direction and origin of the magnetisation

The kimberlite samples have been subjected to both alternating field and thermal demagnetisation. The directions of magnetisation after the application of these techniques are as follows.

Alternating field demagnetization in 5 to 20 mT; declination D = 333,8°, inclination I = -70,4°, α_{95} = 4,5°: thermal demagnetisation at 400°C; D = 332,2°, I = -72,7°, α_{95} = 3,6°.

Here α_{95} is the angular radius of the cone of 95% confidence for the mean direction of magnetisation. Statistically these two directions are identical at the 95% confidence level. All samples showed stability of magnetic properties with respect to both alternating field and thermal demagnetisation. Although the direction obtained is very close to that of the present Earth's field at Kimberley (D = 340,0°, I = -65,3°) it is significantly different, and this supports the contention that the direction obtained was not acquired in the present Earth's magnetic field.

The directions of magnetisation of inclusions of Ventersdorp lavas and the lavas very close to the kimberlite contact were updated by the heating effects of the kimberlite intrusion. The direction of magnetisation of one inclusion (D = 343,0°, I = -72,1°) was identical to the kimberlite direction and the directions removed by demagnetisation of the lavas on the contact and the other inclusion were close to the kimberlite direction. This effect diminishes with distance from the contact (1).

It may therefore be concluded that the direction of magnetisation obtained is that of the Earth's field at the time of the kimberlite intrusion approximately 85 m.y. ago (2).

A Virtual Geomagnetic Pole may be calculated from this direction of magnetisation. However, the time during which this magnetisation was acquired was almost certainly less than the time necessary to average out secular variation. As a result the pole calculated cannot be considered a palaeomagnetic pole (a full study, at present in progress, of several pipes is expected to yield a palaeomagnetic pole). The near pole, so calculated is at 53,8° E and 57,2° S which is close to the poles of the Mesozoic Quasi-Static Interval (3,4) of mean position 80,8° E and 64,5° S, the angle between them being 14,6°. This supports the radiometric age of 85 m.y.

Intrusion Temperature

An attempt has been made to determine a maximum for the temperature of the intruding kimberlitic material by analysis of the magnetic updating of the Ventersdorp lava contact. It was necessary to use a mathematical model of the kimberlite pipe and heat flow therein. On the basis of this model an emplacement temperature was calculated from the results of thermomagnetic experiments on Ventersdorp lava contact samples.

It was assumed that the magnetization of the specimens in question obeyed Neel's equation

$$\delta p = \frac{1}{c} e^{-\frac{E}{kT}} \delta t$$

where δP is the probability that a grain will reverse its magnetic moment in a time δt when at the temperature T K. E is the energy barrier that must be overcome for a reversal to occur, k is Boltzmann's constant and C is a frequency factor. This equation predicts the time required for the relaxation of a magnetic direction, the rock being at a temperature of T K. The frequency factor C is of the order 10^9 to 10^{10}. The value used in calculations has been 10^{10} as this gives a higher value for the emplacement temperature.

The model used for the kimberlite pipe was that of a dyke of rectangular cross-section (220 m x 29 m) and infinite vertical extent. These values were chosen to give the same length and area as the pipe at the 590 m level. The amount of kimberlitic material involved was therefore the same. It was assumed that the latent heat of solidification of the material was negligible, that the thermal properties of the kimberlitic material, solidified kimberlite and country rock were the same and that the effects of transport of heat by volatiles from the kimberlite and of convection in the kimberlite were negligible. It was assumed that the kimberlite was intruded into the rectangular cross-section at a uniform temperature, the country rock being at 20°C. Under these conditions an analytical solution for the differential equation of heat flow exists (5).

Thermomagnetic analysis of lava specimens actually on the contact with kimberlite shows that these specimens contain a considerable number of magnetic grains which are still magnetised in the Ventersdorp direction. Thermal demagnetisation at a temperature less than or equal to 550°C will therefore remove the kimberlite direction from these specimens. An iterative numerical integration of the solution given in (5) was performed to determine the emplacement temperature which would, according to Neel's equation, have had the same magnetic effect as laboratory thermal demagnetisation at a temperature of 550°C. The result obtained implies an emplacement of temperature of less than 620°C.

The simplifying assumptions made above all affect the calculations in such a manner as to give a result for the emplacement temperature which is too high (6,7). The temperature given above is therefore an upper limit.

Further thermomagnetic analysis in progress in an attempt to determine the temperature which is actually required to remove the kimberlite direction of magnetisation. Results of these experiments may give an upper limit to the emplacement temperature even lower than 620°C.

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