THE MAGNETIC "POSTTURBATION" AND THE CURRENT-VORTICES OF SCHMIDT.

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The recent article, by Dr. Adolf Schmidt, in the *Meteorologische Zeitschrift*, 1889, p. 385, entitled, "Über die Ursache der Magnetischen Stürme," induces me to return to my paper, published in the same journal (1895, p. 321), "Die Erdmagnetische Nachstörung." The phenomena of disturbance described in my paper, examined anew by the light of Dr. Schmidt's considerations on moving current-vortices, furnish, in my opinion, new indications for an explanation of the nature of magnetic disturbances. For this purpose I propose to recapitulate briefly the chief results of the investigations concerning the phenomenon described by me, which I term the magnetic "postturbation," or the magnetic after-disturbance effect.

The daily means of the magnetic elements observed at the different observatories formed the principal basis for these inquiries. A superficial look at those quantities—e. g., for Pawlowsk—shows that immediately after a magnetic storm the horizontal force is generally less than it was before, and that it increases during the following days. A synoptical tabulation of a number of such series of diurnal means confirmed this result; it showed, in the majority of cases, that the horizontal force increases regularly after any magnetic storm, and that the westerly declination decreases. The vertical component mostly decreased, though not with the same regularity.

The daily means furnish the three elements of the average vector of the magnetic force. The differences between the daily means gives the differential vector, and in case these differential vectors preserve the same direction for consecutive days, it is evident that a continuous disturbance, with increasing or decreasing force and constant direction, is at work. Now, if a number of series of consecutive days were considered, each of them following a magnetic storm, and if the average were taken of the daily means for the *first* days of these series, then the mean of the daily means for the *second* days, and so on, these mean daily means showed in fact the just mentioned peculiarity as to the horizontal components. For Pawlowsk they indicate the existence of a disturbing force to the south with a rather constant azimuth of S. 20° E.

This constancy in the azimuth of the disturbing force does not present itself in each series of consecutive days taken by itself; it is only from the mean values for a certain number of series that the variability disappears. However, it suffices to consider a rather small number of

series. Moreover, in order to detect this constancy of the azimuth, it is not necessary, as I did at first, to confine the calculations to the "quiet" days following magnetic storms.

Any one familiar with magnetograms knows that during a magnetic storm the registered curves show two characteristics: firstly, strong oscillations; secondly, a rising or falling of the curve as a whole. Whereas, these oscillations mostly compensate each other, the influence of the rising or falling over the whole of the curve will remain; only when the storm is at its highest degree, some few oscillations are apt to become so extraordinarily great as to make this influence imperceptible.

If we call the days with strong oscillations "stormy days," and the others "unquiet days," I found that the unquiet days after a storm show quite the same disturbing force as the quiet days. It is, however, a matter of course that the changing influences of these oscillations only disappear in the average of a sufficient number of series of unquiet days.

Every magnetician is aware of the impossibility of selecting a wholly undisturbed day, and knows that even the so-called normal days, "Normaltage," but seldom deserve this name. It was a remarkable result that the daily means of the normal days at Pawlowsk, which have certainly been selected with sufficient care, showed the same disturbing force again. For forty-one couples of consecutive normal days (that is, days normal as to the three elements) we got an average difference in daily mean of¹

Horizontal component	magnetic east	= 0.000010	C. G. S. units	} azimuth S. 17° E.
"	"	"	"	
Vertical	"	"	"	
	south	= 0.000035	"	
	downward	= 0.000005	"	

In order to inquire whether this disturbing force should show any diurnal inequality, the hourly means were used, as were the daily ones before, the differences between the corresponding hours of a number of consecutive days being tabulated. The result of this calculation was that, among others, the disturbing force at Pawlowsk makes a great regular diurnal oscillation, with this chief characteristic that the greatest deviations from the average azimuth take place at about 8^h A. M. and about 7^h P. M.; whereas, the average azimuth is passed through between 1^h and 2^h P. M.

For unquiet days following a storm, and for quiet days, Normaltage, the diurnal inequality may be taken to be the same. This diurnal inequality may be nothing else than Dr. Lüdeling's daily period of magnetic disturbance.² For further inquiry the available observations of nearly

¹ These quantities were given in my paper in the *Meteorologische Zeitschrift* erroneously as expressed in Gaussian units.

² Dr. G. Lüdeling. Ueber die tägliche Periode des Erdmagnetismus und die erdmagnetischen Störungen an Polar Stationen. *Terrestrial Magnetism*, Vol. IV, p. 245.

all observatories were gone through, and in spite of numerous difficulties it was concluded that this disturbing force was present, and at the same time the characteristic azimuth was determined.

GEOGRAPHICAL AZIMUTH OF THE DISTURBING FORCE AT TWENTY-EIGHT STATIONS.

Lady Franklin Bay,	E 45° N?	Tiflis,	S 15° E
Godthaab,	S 28 E	Nova Zembla,	S 22 E
Kingua-Fjord,	S 27 E	Barnaul,	S 11 E
Point Barrow,	S 24 W	Nerchinsk,	S 9 W
Fort Rae,	S 4 E	Zi-Ka-Wei,	S 6 W
Toronto,	S 1 E	Manila,	S 3 E
Washington,	S 7 E	Bombay,	S 8 E
Cape Thorsen,	S 40 E	Batavia,	S
Jan Mayen,	S 42 E	Para,	S ?
Bossekop,	S 25 E	St. Helena,	S 12 W
Sodankylä,	S 18 E	Cape of Good Hope,	S 13 W
St. Petersburg—Pawlowsk,	S 20 E	South Georgien,	S 8 E
Greenwich,	S 18 E	Cape Horn,	S 12 E
Pola,	S 8 E	Hobartown,	S 12 W

These twenty-eight azimuths were sufficient, as far as the Northern Hemisphere was concerned, for drawing an admissible system of meridians, which at every point indicate the direction of the horizontal component of the disturbing force. From the map in the above-mentioned paper, it appears that this system of meridians corresponds very closely with the system of orthogonal trajectories of the isochasms (lines of equal frequency of the aurora polaris), and that it seems to issue from a pole situated between the geographic and the magnetic North Pole.

For twenty-two stations the vertical component of the disturbing force was investigated with similar results. These results lead to the division of the disturbance phenomenon into two parts: The first and more constant part, due to a system of disturbing forces, everywhere directed perpendicularly to the isochasms, always present, strongly increasing at every storm, afterwards decreasing in a lessening rate; the second constituting the magnetic "unquietness," and caused by a strongly varying system of forces.

Applying Dr. Schmidt's considerations on current-vortices as the causes "of magnetic storms, it is at hand to regard this second part as caused by these moving vortices. The first part according to present interpretations of disturbances, will likewise be most easily explained by electric current systems." Dr. Schmidt already remarks that during a magnetic calm the current vortices probably will be very extensive and at great distance.

The general behavior of the horizontal component of the disturbing force immediately points to the existence of vast current-vortices, which circle the Earth along the isochasms. On the following questions: Do these vast current-vortices lie chiefly within the atmosphere or within the Earth's crust? do they move, or are they stationary? how is the

current-intensity distributed? my researches of 1895 give no certain answer. For these purposes the reductions ought to have been made otherwise; especially the disturbance effects of the same storm at different stations ought to have been investigated.

However, though we can not reply to these questions, we may point to certain analogies, such as have been remarked already by Dr. Schmidt. He writes: "Gewisse von Wild, Wykander und Anderen erhaltene Resultate über die Lage der wichtigsten und einflussreichsten Störungsherde und ferner die schon jetzt vorliegenden Feststellungen über die tägliche Periodicität der Störungen und ihre nach verschiedenen Richtungen verschiedene Häufigkeit lassen den Schluss zu, dass die diesen zu Grunde liegenden Stromwirbel vorzugsweise an bestimmte Stellen der grossen Stromsysteme, welche die tägliche Variation hervorrufen, gebunden sind, ähnlich wie die Theilminima der Luftdruckvertheilung mit Vorliebe am Rande der grossen Depressionen auftreten." We may, in the first place, remark that the isochasms or lines of equal frequency of aurora polaris, which determine the direction of the great current-vortices, run parallel with the path followed by most atmospheric storms. This as far as the northern hemisphere is concerned; for the southern one, our knowledge is still too inadequate. Further, the aurora polaris shows a strong daily inequality, and it is admissible, therefore, to attribute to the isochasms a corresponding shifting over the Earth's surface; it is, therefore, a conceivable result that our vector of disturbance executes an oscillation which points to a shifting of the great current-vortices.

The phenomena of the ordinary daily inequality of the terrestrial magnetic force are attributed, with a fair degree of certainty, to the revolution of a system of magnetic forces or electric currents without the Earth's crust, accompanied by induced currents within the crust. Our vector of disturbance has these characteristics in common with the vector of this inequality; viz., that it is greater in the summer than in the winter, greater at a maximum of sun-spots than at a minimum, and greater in the regions of maximum aurora-frequency than in those of lesser frequency. These analogies point to the conjecture that the great current-vortices, to which we have attributed the disturbing force examined in this paper, also are situated chiefly without the Earth's crust.

BATAVIA, May, 1900.