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The Effect of Geologic Inequalities on the Path of Lightning, as Indicated by Model Experiments

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Abstract

To investigate the influence of lightning strokes on surfaces with geologically non-homogenous structures, experiments were carried out in a model test tank filled with dried sand; and in this a vein of iron ore or other materials. Artificial lightning discharges against the surface of the test tank were undertaken by the aid of an impulse generator at voltages of one million volts and spark lengths of 75 and 170 cm respectively. It was found that a discharge from a positive electrode was pronouncedly influenced by a geological discontinuity as an iron ore vein. On the other hand, negative strokes hit the sand surface at random more independent of geological discontinuities. The difference in effects from the two polarities is related to the mechanism of the discharges and the development of leaders initiating the main discharges in the form of lightning ones.

Several authors[1] have maintained that the geologic structure of the earth exerts an influence on the path of lightning from cloud to earth and that therefore lightning will strike in some places more often than in others.

One of the earliest statements in this regard was made by the Swedish author Olaus Magnus in his famous publication, »Historia de Gentibus Septentrionalibus", Rome, 1555. In the first chapter of his sixth book, Olaus Magnus wrote:

"Nature itself shows by many symptoms where these [ore deposits] are located. They will mainly be found on mountains which have rounded summits without ravines. When lightning strikes such mountains at the summit, on the side, or at the foot, it opens up the silver vein glittering in the clefts."

Following this same line of reasoning, prospectors have looked for ore deposits in areas where the local population reports that lightning strikes frequently. This method has been used especially in certain regions of Africa.

The danger of lightning is especially great over a non-homogeneous surface covered by soil that is a poor conductor. On the other hand, a surface that possesses the same electric qualities everywhere is not apt to produce concentrations of lightning, sometimes termed "lightning nests".

[1] See references at the end.

To confirm the above statements by observations in nature is very laborious and largely a matter of accident. As we shall see, only the rarely occurring positive lightning is influenced by geologic subsoil. This makes it even more difficult to obtain direct corroboration in nature. It is even doubtful whether direct observations can yield ultimate proof. The geoelectrical qualities of the subsoil are variable, all circumstances cannot be defined with certainty, and the influencing factors cannot always be identified. Therefore it seems desirable to test the validity of the hypothesis by model experiments in the laboratory. Attempts to obtain confirmation in nature should of course follow.

Such experiments were made at the Institute of High Tension Research in Uppsala. This report is preliminary; a more exhaustive paper will be published later in the new Arkiv för geofysik of Kungl. Svenska Vetenskapsakademien, Stockholm.

Experimental equipment

The model consisted of a wooden box with a sheet iron bottom (2×3 m) which was set up horizontally and grounded. The box was filled with dry sand to an average depth of 22 cm. A streak or vein of dry iron ore or loam powder about 7 cm wide was arranged in the sand so as to extend across the box and to reach to the bottom. Granite stones were also placed here and there in the sand and small metal disks were put on top of it in an attempt to represent a geologically unequal subsoil.

Vertically above the sand surface, at a stroke distance of 75 to 170 cm, a rod or ball (diameter 25 cm) was placed to act as a voltage electrode. The electrodes were placed sometimes directly above the vein and sometimes displaced sideways. The impulse generator used had a nominal impulse wave of $1/50$ μsec. One pole of the generator and the bottom plate of the box were grounded. All experiments were conducted with minimal breakdown voltage.

There were made 100 discharges on the model surface for statistical evaluation of the paths. These paths were drawn on tracing paper. It was assumed that 100 discharges would suffice to exclude chance and to bring out any tendencies which might exist.

Positive Discharges

A number of preliminary experiments were made with discharges to a metal sheet covering the sand surface. When this was done, the sparks were distributed over the whole soil surface in accordance with the law of probability. It became evident that both polarities have the same properties. Thus we can conclude that it is impossible to predict where lightning will strike on a surface that is a good conductor. All parts of the surfaces have the same electrical properties, and choices of lightning path are quite accidental.

When experiments were made on the sand surface containing the iron ore vein, results were completely different. In case of a geologically unequal surface composed of matter of different electric properties the (conductivity of the iron ore vein is 300 times larger than that of the sand surrounding it), polarity has a decisive significance. The better conductors used in the model strongly influence the path of the lightning — *but only in the case of positive polarity*. In such cases, "lightning nests" can even develop in a homogeneous sand layer due to small local inequalities of the electrical property.

If it were possible to apply the results of the laboratory experiments to nature, we would observe the following properties of lightning. Positive lightning is influenced by the vein up to an angle of incidence of 45°. If the cloud is situated exactly above the vein, all the strokes will hit the vein, with preference for the edges. Even with an angle of 55°, veins will attract about 80 % of the sparks. In this case, the so-called "creeping-paths", form. The stroke at first hits the sand in front of the vein, then jumps to the vein, creeping along the surface. (Fig. 1.)

This indicates that positive lightning prefers to strike superior conductors such as veins, faults, humid crevices, etc. Positive lightning therefore tends to be grounded with preference in such areas and sparks creeping on the surface will endanger objects located there. Thus, when there is positive lightning, the location of the cloud with respect to the vein determines whether the vein will protect or endanger objects. Not only veins, but also good surface conductors, such as moist crevices in mountains can have a moderate in-

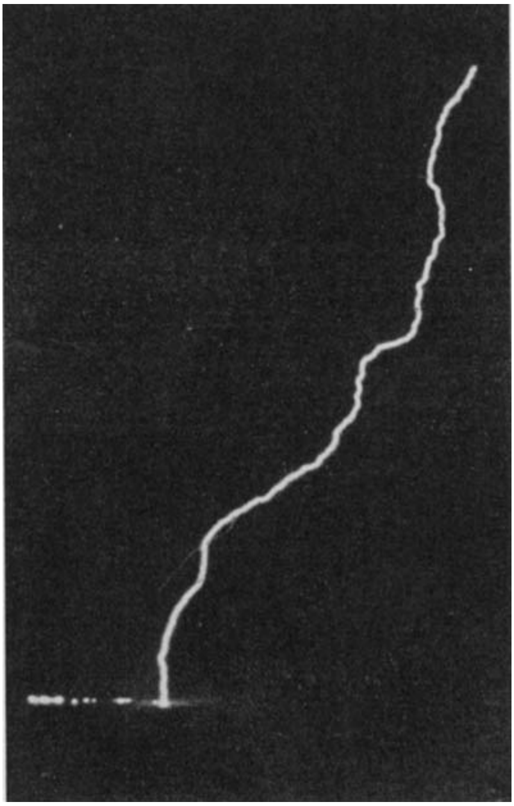

Fig. 1. Positive discharge. The spark has hit at a distance of 13 cm in front of the vein and has then crept to the vein on the surface. Stroke distance, 75 cm.

fluence on positive lightning. Strokes of lightning have been observed which "ploughed" long paths along the surface, terminating in a crevice.

Negative Discharges

During the laboratory experiments, negative lightning showed different properties than positive. Negative discharges when made to the homogeneous sand surface hit at random, as in the case of the metal plate. There is no tendency toward steering. This random distribution of strikes persists even with a non-homogeneous sand surface, for instance with vein. In correspondence with this result one may conclude that if a negative cloud lies directly above the vein, one cannot expect that it will strike the vein as the positive lightning does. Discharges will occur near the vein and sometimes the stroke will hit the vein. At other times, however, it will strike in the surrounding sand surface. A tendency toward creeping paths was seldom observed in the model experiments with negative discharges.

Thus, objects near the vein are not protected by its presence from negative strokes but are always endangered since the vein has some capacity for attraction. During lateral displacement of the electrodes, the vein loses its effect on the path of lightning more rapidly than with positive lightning. Under these circumstances, therefore, the existence of a well-conducting vein is less dangerous to objects during negative than during positive lightning. The different properties of both polarities are shown in fig. 2 and 3.

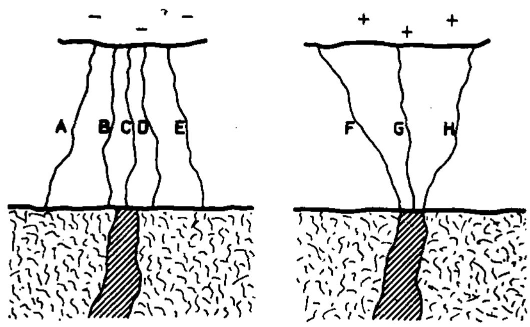

Fig. 2. The cloud is above the vein. A—E—arbitrary paths of lightning with negative polarity (left). No place, even at a distance from the vein, is safe from being hit.

With positive polarity (right) the probable path of lightning lies between F and H. The other part of the surface is free from discharges.

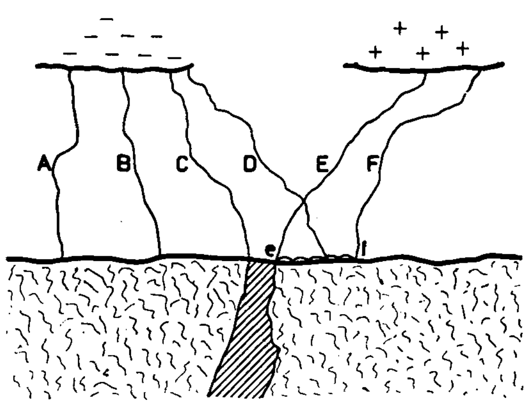

Fig. 3. The cloud is displaced laterally from the vein. A—D arbitrary paths of lightning with negative polarity. The whole surface is endangered. The vein increases the danger only by a small amount.

Between E and F—preferred path of lightning with positive polarity. The line e—f is especially endangered.

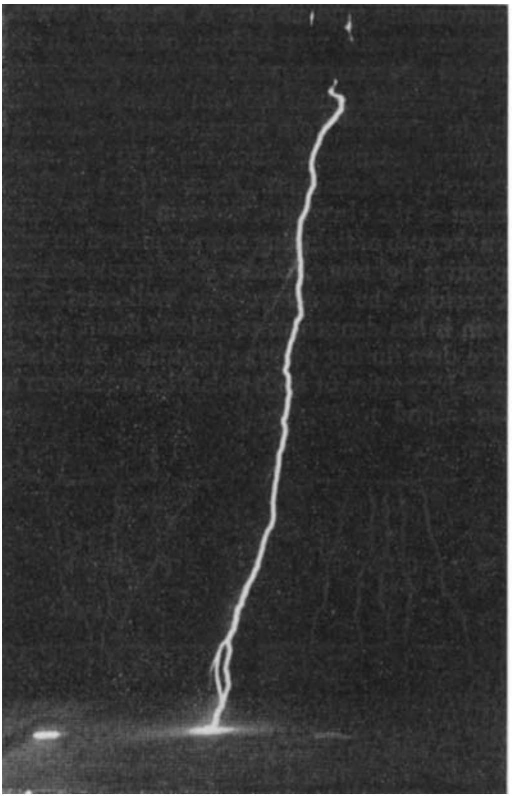

Fig. 4. Positive discharge: Long upper (positive) and short lower (negative) leader. The place of juncture is given by the loop.

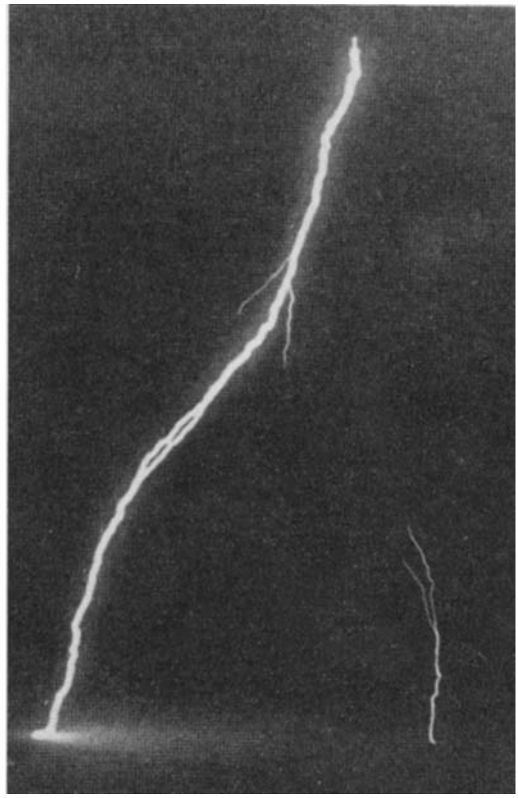

Fig. 5. Negative discharge: The meeting point of both leaders (loop) lies about at the middle of the distance. Note especially the dying lower subleader at the right hand.

The different behavior of the positive and negative lightning is presumably due to different mechanisms of development. In order to answer this question, we have begun special examinations. Preliminary experiments have shown that upper and lower leaders are present where there is a poor conducting, non-homogeneous soil plate. Their meeting initiates the stroke. During positive discharges, the upper (positive) leader covers nearly the whole distance. The lower (negative) leaders are short. We suppose that "lightning nests" form where the ground can attain greater field strength because of stronger electric properties favoring development of the lower (negative) leader. Fig. 4 shows a positive discharge with long upper and short lower leaders. The loop in the lightning trace indicates their meeting point.

During negative discharge, both leaders have always been observed. Both have about equal length and junction occurs roughly in the middle of the distance (fig. 5). Lower leaders are found more frequently in this case. It is a question of chance which of the many lower leaders first joins the upper one to determine the direction of the main discharge. In consequence, lightning hits all over the surface; the vein loses the character of concentrator; even the portion of the sand surface that closely adjoins the vein is hit occasionally.

Conclusion

In summary, it appears that the model experiments have answered the question of the existence of "lightning nests" and shown that their formation is closely connected with the polarity of lightning. Positive lightning preferably strikes places with good electric pro perties. There is a marked tendency toward formation of "lightning nests"; and protective measures are more effective.

It is more difficult to predict where negative lightning will strike. It does not exclusively hit places with well-conducting subsoil; it also hits surrounding soil which is a poorer conductor. Protection therefore does not have the desired effect. The zone protected by an installation is narrow; the formation of "lightning nests" is poorly developed.

It is necessary to take note of these facts since natural lightning comes from clouds charged either positively or negatively. Percentage distributions have often shown that about 90 % of all lightning comes from negatively charged thunderstorm clouds. There are, however, exceptions, depending on the conditions in the atmosphere. From this viewpoint, the question of the electrical polarity of the thundercloud has the greatest significance.

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