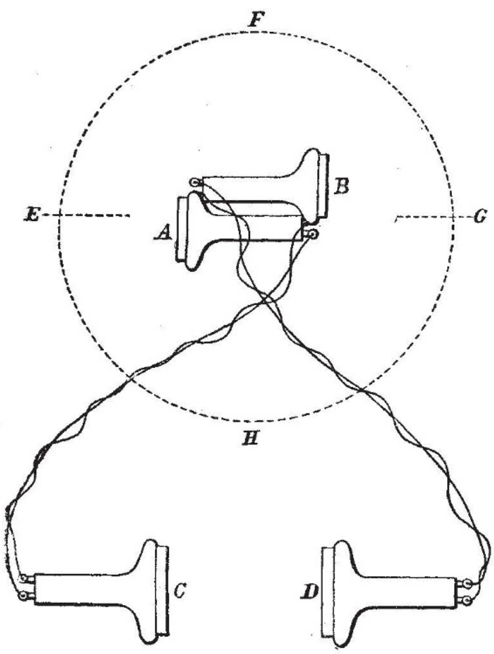
general result was as follows: imagine a globe, E, F, G, H, in the interior of which are the telephones A and B; let E and G be the two poles, and imagine the usual meridian lines and parallels of latitude. It was found as the result of the experiments that the observer at C, D could determine with tolerable accuracy the *latitude* of a sound made near A, B, but that *he had no idea whatever of its longitude.* In a later experiment two Blake transmitters were employed. They were placed back to back at about five feet from the ground in the open air. The receiving telephones were indoors, whence the speaker could be observed. The results of observation coincided with those already described. In order more closely to imitate the natural arrangement of the ears the transmitters were then set so that the diaphragms were at 45° to each other. A sound made at H here produced a feebler effect than one made at F; and *after a few experiments* the ear seemed to be able to distinguish whether the speaker were in front of, or behind the transmitters. Unfortunately the two transmitters were not equally sensitive, and the ear had to get accustomed to the slight inequality in the intensity



of the transmitted sounds. Prof. Bell suggests that the sensations experienced by deaf persons might be studied by persons possessed of normal hearing powers by purposely using transmitters of unequal power, or by introducing artificial resistances into the circuits.

It also occurred to Prof. Bell that the telephone might afford a means of ascertaining to what degree the human ear normally has the power of appreciating the *direction* of sound. For this purpose a number of telephones were hung up in different parts of a summer-house, and were connected with a switch-board so that an interrupted current from a rheotome in a distant place could be sent through any one at will. A person stationed at the middle of the summer-house, with his eyes closed, and holding his head perfectly still, was required to indicate the point from which the sound seemed to emanate. The indicated direction usually differed considerably from the true direction, and it was found that the observer soon came to recognise each individual telephone by its particular timbre. To obviate this a single telephone was hung up in different parts of the summer-house during the absence of the observer. This was very laborious; nevertheless a long series of experiments were carried out, and their results carefully set down in a series of eight tables. Five young men were employed as observers, the power of each of their ears being previously ascertained by an independent test. The experiments thus carefully made and tabulated are still too few, and in Prof. Bell's opinion too imperfect in several respects, to admit of accurate generalisation; but some deductions are unmistakable. The tables establish beyond dispute (*a*) that the perception of the direction of a source of sound is less perfect by a single ear than by both ears; (*b*) they disprove the idea that direction cannot be appreciated by monaural observation; (*c*) they show that the direction of sound is more accurately defined as it approximates to the axial line of the ears [this entirely negatives Steinhäuser's theory of binaural audition]; (*d*) that the indications are proportionately at fault as the true source is in any other direction, the angular error sometimes amounting to 180° when the source is 90° from the axial line! (*e*) the perception of direction is absolutely unreliable when the source of sound is at the nadir with respect to the observer. It should however be remembered that in experiments thus made in an apartment reflexion of the sound comes into play, and partially vitiates any general deductions by introducing slight though unknown complications.

The method adopted by Prof. Bell to measure the relative hearing power of the separate ears was as follows:—Two flat coils of wire were placed upon a long wooden rod which passed through their centres. One of these coils, the "primary," was a fixture, and was put in circuit with a battery and a vibrating interrupter in a distant room. The other coil, the "secondary," was joined up to a telephone. When placed close to the primary the induced current produced loud sounds; the observer, holding the telephone to his ear, was then directed to slide the secondary coil away from the primary until he ceased to hear anything. The distance between the two coils was then measured. It will be seen that this arrangement anticipated to some extent the sonometer of Prof. Hughes.

We venture to hope that Prof. Bell will continue these interesting researches in this promising, and hitherto almost unexplored field. S. P. T.

THE GEOLOGY OF THE LIBYAN DESERT[1]

IN his very interesting anniversary address before the Academy of Sciences in Munich Dr. Zittel has brought together all the known facts concerning the geology of the northern districts of Africa, in a manner which is calculated to render the greatest service to his fellow-workers in science. The address, with its accompanying map and numerous explanatory notes, constitutes indeed by far the best monograph on North African geology which has yet appeared. The author not only reviews the works of the various travellers who have furnished materials bearing upon the question, from Browne and Hornemann to Fraas, Rohlfs, and Schweinfurth, but what is of far more importance, gives the results of his own accurate study of the rocks and fossils collected and brought home by recent investigators. The general results arrived at by Dr. Zittel are as follows.

To the east of the Nile rises a mountain range composed of highly crystalline rocks—granite, diorite, and hornblendic gneiss. The peaks of this range rise to heights varying from 5,000 to 8,000 feet.

The oldest stratified rocks of the district appear to be of Cretaceous age. Lying upon the axis of crystalline rocks, and also covering wide tracts of country to the south of the Great Desert, is found the Nubian sandstone

[1] "Ueber den geologischen Bau der libyschen Wüste. (Festrede gehalten in der öffentlichen Sitzung der k. b. Akademie der Wissenschaften zu München zur Feier ihres einhundert und einundzwanzigsten Stiftungstages.) Von Dr. Karl A. Zittel.

formation. Concerning the age of these sandstone rocks a considerable amount of controversy has taken place in recent years, and they have been referred by different authors to the Triassic, the Jurassic, and the Neocomian systems. The fossils found by Overweg and others, however, seem to leave no room for doubt that the real age of the Nubian sandstone is the Cenomanian, or lower portion of the Upper Cretaceous.

Lying upon these sandstones are found great deposits over 600 feet in thickness, consisting of dark green and grey, finely-laminated marls in their lower, and of white, earthy limestones in their upper part. These rocks contain many characteristic Upper Cretaceous fossils, such as *Ananchytes ovatus*, *Ventriculites*, and *Rudistes*. These Upper Cretaceous rocks have been found not only forming the whole southern margin of the Desert, but also rising above the sandy wastes in the hilly masses which form the oases.

The deposits which underlie the greater part of the Sahara appear to be of Tertiary age and referable to the Nummulitic and Miocene periods. There would seem to be no sharp line of demarcation between the Cretaceous and the Tertiary deposits in this area, and in this, as in many other particulars, which are pointed out by Prof. Zittel, the North African formations of these periods remind us of those of the Rocky-Mountain regions of North America.

The older Tertiary deposits of Northern Africa are divided by Dr. Zittel into two members, which he designates the "Lybysche Stufe" and the "Mokattam Stufe." In the lowest of these (the Libysche Stufe) a widely-spread and very characteristic fossil is the Belemnite-like *Graphularia desertorum*, Zitt.; many nummulites and other well-marked Eocene fossils also occur.

There appears to be still some doubt as to whether the "Mokattam Stufe" of Dr. Zittel should be classed as Eocene or Oligocene.

In the northern part of the area various freshwater and marine deposits are found which are now referred to the Miocene. No less than sixty-eight forms of marine mollusca have been determined by Dr. Theodor Fuchs as occurring in these beds, and he is led to regard them as indicating a horizon not far removed from that of the Leitha-kalke of the Vienna basin.

The several formations described succeed one another from south to north, this being the direction of the dip of the beds; their relations to one another are well illustrated in the map and sections which accompany the work.

In the midst of the Beharieh oasis a mass of igneous rock is found rising through the midst of the Upper Cretaceous limestones. This rock has been studied by Prof. Zirkel of Leipzic, who pronounces it to be an ordinary plagioclase basalt, very similar in character to that of the Giant's Causeway in Ireland.

Over the whole of these formations the great mass of sands of the Desert is spread, and rises in places into hills several hundreds of feet in height.

In reading this address we cannot but feel that Dr. Zirkel has made admirable use of the collections which Dr. Schweinfurth and others have placed in the museum at Munich; and that by their careful study he has been enabled to clear up many of the difficulties which every one must have felt who has endeavoured to understand the geological structure of the great African continent.

PHYSICS WITHOUT APPARATUS[1]

VIII.

IN the preceding articles of this series we have shown how in every department of physics a large number of instructive experiments may be performed without the aid of any more formal apparatus than the usual domestic appliances of an ordinary household. There remain to be described a few miscellaneous experiments before concluding the subject.

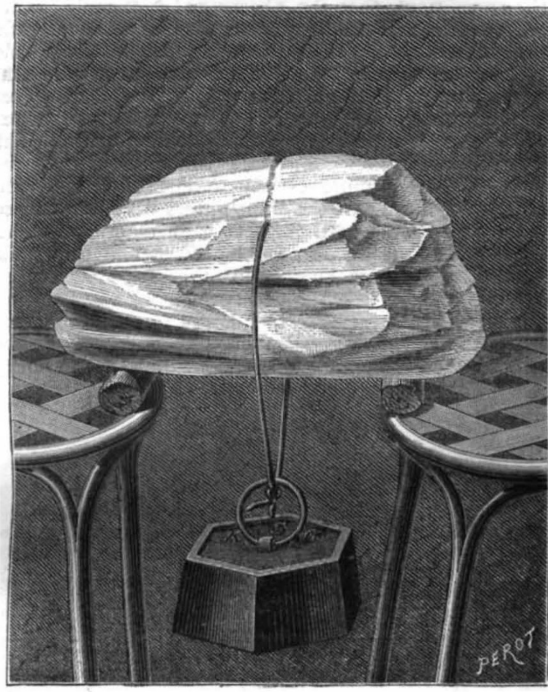


FIG. 25.

Many years ago Prof. Faraday observed that if two pieces of ice are pressed against one another they freeze

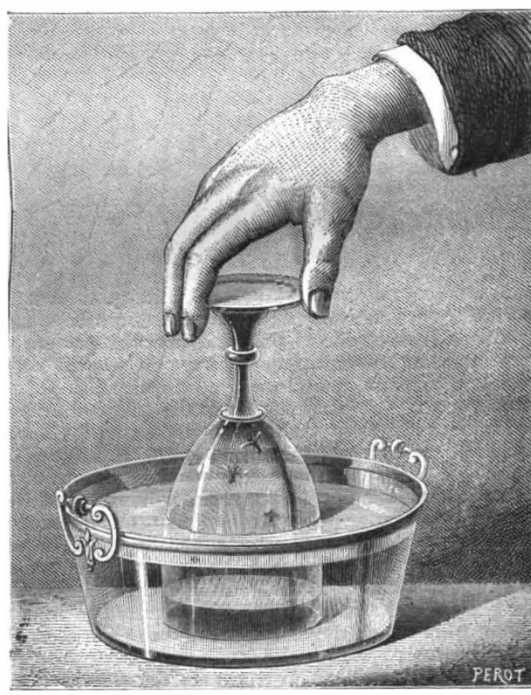


FIG. 26.

firmly together at the point of contact, even though they may themselves be thawing at the surface. To this

[1] Continued from p. 538.