to determine the magnetic declination for each point of observation. This may be done by directing the sights along one of the lines that has been set out, and reading the bearing, after the first magnet and iron rod have been removed. Observations must also be made along the magnetic meridian north of the supposed ore pole to determine where the north-seeking end of the free needle changes its direction from north to south, or whether it invariably points toward the north. When these determinations of declination, horizontal intensity, and inclination have been carefully made and the angles obtained noted on paper divided into squares, lines are drawn for each of the three series of observations, exhibiting equal declination (isogonic lines), equal intensity (isodynamic lines), and equal inclination (isoclinic lines). This is done in each case by joining the points for which equal angles were obtained. The curvature of the lines is drawn as naturally as possible, care being taken to avoid sharp bends. The curves of inclination and intensity thus constructed are closed, and have an approximately circular or elliptical shape, provided that a single isolated ore mass is being dealt with. They are grouped round two points. The one at the north is where the greatest angle of deviation was found, while that at the south is where the smallest angle was obtained. Between these two groups of curves is an open curved line representing the neutral angle. In this neutral line the intensity is the same as if no ore was present. The straight line joining the points where the greatest and smallest angles were obtained passes over the center of the ore mass, and indicates the direction of the magnetic meridian of the ore field. Directly beneath a point in this line, in a vertical ore bed, the greatest mass of ore occurs. The rule that most generally holds good in searching for iron ore is that the ore mass is to be found immediately beneath the point where the magnetic meridian cuts the neutral line. The isogonic lines consist of concentric ovals placed, as a rule, symmetrically on both sides of the meridian. From the shape and position of these curves useful indications may be obtained regarding the position of the ore pole and the shape of the deposit.

TIBERG'S METHOD.

The instruments employed by E. Tiberg consist of a new magnetic instrument for determining the inclination, a plane table, and a sighting instrument. The inclination instrument consists of a round box $3\frac{1}{4}$ inches in diameter and $\frac{1}{2}$ inch deep, fixed in two square brass frames with $3\frac{1}{2}$ inch sides. At its circumference it has a graduated ring, and in the middle a magnetic needle 2.36 inches in length. Its axis is at right angles to the plane of the box, and rests upon two agate supports. The needle can thus move freely when the instrument is placed horizontally or vertically.

The instrument differs from other instruments for determining inclination in that the center of gravity of the magnetic needle is a little below its horizontal axis when the instrument is in a vertical position. The needle is compensated for the vertical force of the earth's magnetism by a piece of wax fastened to its south-seeking end. The instrument is provided with a spirit level for horizontal adjustment, and with a ring, by means of which it can be suspended vertically. The sighting instrument is a brass plate about a foot in length, provided at one end with four square flanges to receive the inclination instrument for horizontal measurements. At right angles to this square there is a groove in the plate with a sliding receptacle for the bar magnet required for horizontal measurements. Four folding sights are attached to the plate in such a way that their lines of sight form a right angle. The instrument, consequently, can be used as a crosshead. Two special sights are added for leveling operations, and the instrument is provided with a circular spirit level.

The plane table employed is of the usual form. The observations for vertical measurements are made at the surface with the plane table or by hand. The inclination instrument is fastened to the plane table, leveled, and turned until the needle points to 90°. The instrument is then raised with the ring at the top, and placed at right angles to the magnetic meridian, and the angle indicated by the needle observed. The same operation has to be done by hand if the plane table is not available. When the ore appears to be deep, or when the horizontal intensity is powerful, recourse must be had to the plane table.

The formula for calculating the vertical intensity G is—

$$G = K \tan v,$$

in which v is the angle given by the needle—that is, its deviation from the horizontal—and K a constant varying in different instruments from 0.75 to 1.4 of the earth's horizontal magnetic force. Lines of equal vertical intensity may thus be constructed. In magnetic plans it is usual to employ a blue color for positive intensity, and a red color for negative intensity. The accuracy attainable with this method is from 0.2 to 0.1 per cent. of the earth's magnetic force in central Sweden. With the plane table 250 to 300 observations may be made per day, and 450 to 500 by hand. For each ore field surveyed the needle must be compensated afresh, and a preliminary magnetic survey made. The field is then divided into squares, with sides 40 feet in length. The base line is as near as possible in the middle of the field, and parallel to the direction of the strike of the deposit. In making the survey observations are made every 10 feet, and in some cases every 5 feet in the immediate vicinity of the ore, and every 20 to 40 feet or more when further distant from the ore. The general rule is to make as many observations as may be required to indicate what the appearance of the curves will be.

Heights are estimated by the eye, or by a preliminary leveling with the sighting instrument, and the more important topographical details are noted. The maximum of intensity is generally presented by the point where the ore is nearest to the surface. It may also be situated between two adjacent deposits—in which case the intensity decreases, at first slowly, or not at all, and then comparatively rapidly. The distance to the center of a vertical ore bed may be taken as at least 0.7 of half the breadth of the north polar attraction. This rule is, however, not very trustworthy. The vertical distance of the plane of observation from the upper ore pole is equal to the horizontal distance of the point where the needle deviated most from the horizontal

from that where $\frac{1}{2}$ of the greatest intensity was found. It is also equal to $1\frac{1}{2}$ the distance of the point where the needle dipped most from that where half the maximum was found. The latter rule is the best.

Sometimes these calculations enable an opinion to be formed of the relative values of two similar ore beds. For two deposits of a similar character, situated at least 30 feet beneath the surface, it may be assumed that the deposit for which the product of the greatest intensity and the polar distance is the greater contains the larger quantity of ore for the same length of deposit. If the polar surfaces of the two beds are limited, this product must be replaced by the square of the polar distance. A good idea of a deposit may be formed from the appearance of the curves of intensity. Regular, long extended, elliptical curves, inclosing a long but narrow district of greatest intensity, always indicate a regular lenticular mass. An asymmetrical bend in the curves indicates parallel deposits. More circular curves may indicate a segregation of ore if the intensity decreases regularly. Irregular curves indicate more or less irregular deposits. In exploring for courses of ore in the mine, a base line is marked out in the level, and observations made every ten feet at least. At each station three observations have to be made: 1. To determine the direction of the total horizontal intensity by means of the sighting instrument, the deviation of the magnetic needle from the base line being observed. 2. To determine the magnitude of its force by means of the bar magnet. 3. To determine the vertical intensity by means of the inclination instrument. Vertical measurements must also be made at the top and floor of the level, and for this purpose the instrument may be held in the hand. On neutral ground at the surface, the horizontal force of the earth's magnetism and the direction of the earth's magnetic meridian must be determined. The results of all the observations are represented on paper, along the base line, as arrows showing the horizontal forces of the magnetism of the ore at the points of observation. If all or part of the arrows are directed toward the same point, there the ore may be assumed to be. The ore would be at the level at which the observations were made, if the vertical intensity is negative. When the arrows approach in front or behind, the plane of observation is above or below the magnetic center of the ore. When the vertical intensity is positive, the ore may be above or below the plane of observation, always assuming that a more or less vertical ore mass is being dealt with.

CONCLUSION.

From the sketch of the new methods given above, it will be seen how admirably the principles of terrestrial magnetism have been applied in Sweden for the exploration of iron ores. The results are not only of scientific interest, but also of great practical importance. To illustrate this, it may be mentioned that, by applying his method, Tiberg has discovered very important deposits of ore at the mines of Langban and Sikberg. Some interesting results, too, have been obtained by Professor Thalen, who has been able, with the magnetometer, to determine the various percentages of powdered iron ore and microscopic fragments of magnetic minerals occurring in the various beds of clay at Upsala. In the same way the order of succession of beds of iron-bearing rocks can be determined. It appears, therefore, that accurate magnetic surveys would be of great value to the geologist, as well as to the miner. The value of the improved methods in the exploration and development of iron ore districts cannot be overestimated, and probably a great future is in store for them in solving questions of stratigraphical geology in districts containing magnetic rocks.

ON A NEW METHOD OF MEASURING MAGNETIC SUSCEPTIBILITY AND MAGNETIC PERMEABILITY.

By THOMAS T. P. BRUCE WARREN.

THE following method of measuring magnetic forces opens up an important branch of chemical physics, and makes magnetism itself an interesting adjunct to analytical research.

Ordinary German silver, when tested with a magnet in the ordinary way, shows no attraction whatever, but if examined in this way is decidedly attracted by a magnet. It was, in fact, from examining the contacts of electrical apparatus, to determine what metal or alloy was used, that this method of procedure was developed.

A delicate chemical balance is placed on a firm table, and in the magnetic meridian. A weight of the substance whose susceptibility is required, either in powder or fine filings, is placed evenly on the pan of the balance, and equilibrium carefully made; a powerful horse-shoe magnet is then placed directly under the pan, which is prevented from approaching within a certain distance of the magnet. Care must be taken that, in every case, it should occupy the same position. Of course it would be more convenient to employ an electro-magnet, which could be fixed, and, after adjusting the weights, the magnet could be excited by contact with a battery. When a very intense magnetic field is required, a coil of wire connected with a dynamo is placed under the scale pan.

If we are operating on a paramagnetic or positive substance, the pan will be drawn down by the action of the magnet, and weights will have to be added to restore equilibrium. The weight required to restore equilibrium is a measure of the susceptibility of the substance in hand.

If, however, we are working with a diamagnetic or negative substance, we should expect the pan to be repelled. As these so-called substances are also attracted, we are driven to the conclusion that diamagnetism as opposed to paramagnetism, in its general acceptance, has no existence; still, although a substance may have its poles, relatively to an exciting magnet, as implied by these prefixes, no case of magnetic repulsion has yet been met with.

A carefully balanced platinum crucible was found to be strongly attracted. Bismuth was decidedly attracted, but behaved with a curious sluggishness, which was very much reduced by diminishing the distance. Metallic manganese, although not affected by a magnet in the ordinary way, has a decided influence by this method of testing.

It is preferable in some cases to attach a powerful

magnet to one of the ends of the beam, in place of the scale pan, as we are then independent of the magnetic influence due to the metal of the pan, and, having once balanced the magnet, we obviate the necessity of having to weigh each substance operated on.

We are indebted to Sir William Thomson for the terms magnetic "susceptibility" and magnetic "permeability," and it is in precisely the same sense as used by him that those terms are employed in this paper; thus, "susceptibility" implies that condition which ordinarily is understood of becoming magnetic, and "permeability" may be taken as meaning the power of conversely arresting the transmission of magnetic energy, or a kind of porosity.

In addition to these terms, we frequently use the expressions "retentive power" and "residual magnetism." These terms express what are practically the extremes of the same idea. Many substances are magnets when under the influence of another magnet, but as independent magnets return almost to their zero condition. The power of retaining magnetic polarity, *per se*, deserves a scientific recognition. It has now become a recognized fact that the retentive power of steel can be increased by the addition of other metals; although themselves feebly magnetic, it is generally considered that their influence is due to tempering or hardening iron.

Residual magnetism may be roughly measured by noting first the force which draws the magnet to the substance experimented on, and, after magnetizing by any of the ordinary methods, replace the same and note the alteration in the attractive force. The same method may be used for measuring the rate of acquiring, under a constant magnetic force, the maximum of induced or permanent magnetism.

In experimenting on the magnetic permeability of substances the arrangement of the magnet or magnetic field is the same as in the previous case—a plate of the metal or stratum of liquid is inserted between the magnet and some iron filings or magnet.

When the plate is removed, the magnet is attracted to within a fixed distance of the filings, the weight required to produce equilibrium is noted; the plate is then inserted, and the diminished attraction again noted. The difference in weight is due to the arrest of magnetic influence by the interposed layer.

The effect produced by differences in thickness of the interposed layer does not appear to follow the law of variation for magnetic attraction as generally accepted.

The magnetic permeability is known to be a function of susceptibility. A class of substances appear to exist which are almost magnetic insulators, but as a rule the higher the susceptibility of a substance is, the greater will be its permeability. This we might have expected.

This method of experimenting on magnetic permeability leads to the conclusion that we are not warranted in treating a vacuum as magnetic; on the contrary, we have, simply by exhaustion, altered the permeability of an interposed layer of air. When a magnetic substance is made to approach a balanced magnet, the force of attraction was as follows:

At 41.0 mm. distance	0.026 grm.
" 20.5 "	0.520 "
" 14.0 "	1.300 "

so that at one-third the distance, in this experiment, the attraction is fifty times as great.

The magnetic force is no doubt increased, partly by the diminished distance and partly by increasing the permeability of the intervening layer of air in consequence of reducing the thickness of the stratum.

In order to obtain comparative results, the unit weight is less reliable than the unit volume. It seems to me that the unit adopted must, in the case of a substance of definite chemical nature, be a function of its molecular weight.

I am working on this matter with a view of ascertaining the magnetic equivalents of substances—that is, the weights of substances required to produce the unit force, at the unit distance, in the unit field.

A curious result of this inquiry is that in delicate chemical operations where weighing magnetic substances is concerned, we cannot disregard the intensity and horizontal force in the place where our weighings are made.—*Chemical News*.

PHOTOGRAPHY BY VITAL PHOSPHORESCENCE.

By Dr. JNO. VANSANT.

SOME months ago there was published in several scientific journals* an article in which I showed how excellent photographic positive prints, on glass or paper, could be made from an ordinary negative by means of the transformed or "stored up" radiant energy—the phosphorescent luminosity—of certain inorganic substances, especially particular sulphides of calcium and strontium.

Many organic substances also, as is well known, possess this property of storing up, so to speak, and afterward emitting, as more or less luminous rays, the radiations to which they have been exposed. Crystallized carbon, in form of the diamond, and white paper may be cited as illustrations of this class. A photographic latent image on a bromide of silver surface, capable of being developed, can easily be produced by bringing into contact, for an hour or so, in the dark, such a sensitive surface, and an engraving, or some ordinary printing, on white paper which has been just previously exposed for some minutes to the direct rays of the sun.

But I have now to call attention to the curious fact that the kind of light given out by certain *animal organs*, and which evidently in its causation has some close relation to the nervous system and vitality of the animal, and belongs to a different class of phenomena from the phosphorescence above mentioned, can also bring about incipient decomposition in a haloid salt of silver. Moreover, it can do this through a sheet of glass of the usual thickness used for photographic negatives, and, consequently, there is a possibility of producing by such light photographic positive prints. The following experiment, copied from my notes, proves this:

* SCIENTIFIC AMERICAN SUPPLEMENT, Feb. 12, 1887; *Philadelphia Photographer*, April 16, 1887.

June 8, 1887.—This evening, just after dark, I took about a dozen fireflies (*Lampyris cornuta*), which had been captured a few minutes before on the lawn, and inclosed them in a wide-mouthed vial of some 3 oz. capacity, having a piece of fine white bobinet (such as is used for ladies' veils) stretched over its mouth in place of a stopper. Inclosed thus, they would frequently emit the momentary flashes of greenish tinted yellow light for which they are remarkable, though usually only one insect at the same time would flash. Every few seconds one or another would emit its light for a period which I estimated to average in each case about one half of a second, and the frequency of the emissions could be increased by gently shaking the vial. When not flashing, the under surface of the three posterior segments of the firefly's abdomen, from which the light came, was scarcely at all luminous, but was simply of a bright yellow color. The flashing was plainly under the control of the insect, like its muscular movements. These fireflies are rather less than three quarters of an inch long, and the segments which become luminous have, altogether, an area of only about one eighth of an inch square. The flash is, however, quite bright, so much so that fine print can be easily seen when held close to it.

Repairing to my dark closet with the vial of fireflies, I placed it to one side, under cover, while I arranged and clamped a very sensitive gelatino-bromide of silver dry plate beneath an ordinary negative picture of a landscape on glass, as for contact printing.

The vial of insects was then inverted over the back of the negative, so that only the fine meshes of the bobinet and the glass of the negative with its gelatine film intervened between the fireflies' light and the sensitive bromide plate. I counted the flashes, occasionally shaking the vial and sliding it over the negative, till fifty flashes had occurred.

The vial was then removed, the sensitive plate separated from the negative, and an attempt made to develop the latent image, if any existed. Alkaline solution of pyrogallol was used, and in a few minutes I had the pleasure of seeing a well-marked positive image of the negative picture appear, the plate being somewhat yellow stained, as if from too long an exposure. This was fixed in the usual way with sod. hyposulph., and is now in my possession—probably the first picture ever produced by the light emitted from a living animal organism.

U. S. Marine Hospital, St. Louis, Mo., June 10, 1887.
—St. Louis Photographer.

FREEZING MIXTURES.

TABLE I.—FREEZING MIXTURES.

Composition by Weight.		Reduction of Temperature in Degrees Fahr.	
		deg.	deg.
Ammonium nitrate.....	1 part	From + 50 to + 4 = 46	
Water.....	1 "		
Ammonium chloride.....	5 parts	From + 50 to + 10 = 40	
Potassium nitrate.....	5 "		
Water.....	16 "	From + 50 to + 4 = 46	
Ammonium chloride.....	5 "		
Potassium nitrate.....	5 "	From + 50 to - 3 = 53	
Sodium sulphate.....	8 "		
Water.....	16 "	From + 50 to - 7 = 67	
Sodium nitrate.....	3 "		
Nitric acid diluted.....	2 "	From + 50 to - 12 = 62	
Ammonium nitrate.....	1 "		
Sodium carbonate.....	1 "	From + 50 to - 0 = 50	
Water.....	1 "		
Sodium phosphate.....	9 "	From + 50 to + 3 = 47	
Nitric acid diluted.....	4 "		
Sodium sulphate.....	8 "	From + 50 to - 10 = 60	
Hydrochloric acid.....	9 "		
Sodium sulphate.....	5 "	From + 50 to - 40 = 90	
Sulphuric acid diluted.....	4 "		
Sodium sulphate.....	6 "	To - 5	
Ammonium chloride.....	4 "		
Potassium nitrate.....	2 "	To - 12	
Nitric acid diluted.....	4 "		
Sodium sulphate.....	6 "	To - 18	
Ammonium nitrate.....	5 "		
Nitric acid diluted.....	4 "	To - 25	
Snow or pounded ice.....	2 "		
Sodium chloride.....	1 "	From + 32 to - 23 = 55	
Snow or pounded ice.....	5 "		
Sodium chloride.....	2 "	From + 32 to - 27 = 59	
Ammonium chloride.....	1 "		
Snow or pounded ice.....	24 "	From + 32 to - 30 = 62	
Sodium chloride.....	10 "		
Ammonium chloride.....	5 "	From + 32 to - 40 = 72	
Potassium nitrate.....	5 "		
Snow or pounded ice.....	12 "	From + 32 to - 50 = 82	
Sodium chloride.....	5 "		
Ammonium nitrate.....	5 "	From + 32 to - 51 = 83	
Snow.....	3 "		
Sulphuric acid diluted.....	2 "	From + 32 to - 23 = 55	
Snow.....	8 "		
Hydrochloric acid.....	5 "	From + 32 to - 30 = 62	
Snow.....	7 "		
Nitric acid diluted.....	4 "	From + 32 to - 40 = 72	
Snow.....	4 "		
Calcium chloride.....	5 "	From + 32 to - 50 = 82	
Snow.....	2 "		
Calcium chloride crystallized.....	3 "	From + 32 to - 51 = 83	
Snow.....	3 "		
Potash.....	4 "		

TABLE II.—EVAPORATION OF LIQUIDS.

Liquid or Gas.	Water.	Anhydrous Ammonia.	Sulphuric Ether.	Methylic Ether.	Sulphur Dioxide.	Pictet's Liquid.
Specific gravity of vapor compared with air = 1.000.....	0.622	0.59	2.24	1.61	2.24	
Boiling point at atmospheric pressure, deg. Fahr.....	212	-37.3	96	-10.5	14	-2.2
Latent heat of vaporization at atmospheric pressure, units.....	966	900	165	.....	182	.....
Absolute vapor tensions in pounds per square inch at different temperatures.	deg. Fahr.	lb.	lb.	lb.	lb.	lb.
-40.....	.....	.....	.....	.....	.....	.....
-20.....	.....	19.4	.....	12.0	5.7	11.6
0.....	.....	30.0	1.5	18.7	9.8	15.4
+20.....	.....	47.7	2.6	28.1	16.9	22.0
+32.....	0.069	61.5	3.6	36.0	22.7	27.0
+40.....	0.122	73.0	4.5	42.5	27.3	31.3
+60.....	0.254	108.0	7.2	61.0	41.4	44.0
+80.....	0.503	152.4	10.9	86.1	60.2	60.0
+100.....	0.942	210.6	16.2	118.0	84.5	79.1
+120.....	1.685	283.7	23.5	.....	117.5	99.7
+140.....	2.879	.....	33.5	.....	.....	.....
+160.....	4.731	.....	45.6	.....	.....	.....
+180.....	7.511	.....	62.0	.....	.....	.....
+200.....	11.526	.....	81.8	.....	.....	.....
+212.....	14.7	.....	96.0	.....	.....	.....

CAVERNS NEAR MANITOU, COLORADO.

By H. C. HOVEY.

EVERY explorer of Colorado must have noticed the fact that, while there are many canons, there are few caverns. This fact may be explained by observing the geological peculiarities of the region. The western banks of the Missouri river are only 700 feet above the level of the sea. The plains stretching thence westward to the foot of the Rocky Mountains have a gradual upward slope, reaching finally an altitude of 6,000 feet above the sea. The underlying rocks are broad sheets of sandstone, slate, shales, and limestone. The mountain region was made by an upheaval of the lower rocks, causing them to appear at the surface, namely, granite, gneiss and trap. Along the border line between the plains and the mountains is a narrow but highly interesting region, lying nearly north and south, where the rocks of the plains appear to have been turned abruptly upward and then broken off. They must have formerly extended much farther up the mountain side than now, having since been worn away by the action of the elements. The width of this border region varies from one to twelve miles. It is a sort of geological paradise, where one may cross the edges of all the strata, from the Archæan to the Tertiary, and study to good advantage the history of their folding and erosion.

I observed that, in many places, the sedimentary rocks seemed to have been modified by the former heat of the adjacent eruptive rocks sufficiently to acquire an obscure columnar structure. Perpendicular lines of weakness were thus opened, admitting the rain water, the roots of plants and trees, and otherwise favoring the formation of canons rather than of caverns. But in certain localities the masses of homogeneous limestone were large enough to permit the excavation of grottoes of considerable size.

The most noted of the Colorado caverns are those found in the vicinity of Manitou Springs, and that add

PLOT OF THE CAVE OF THE WINDS.

Scale, 1 in. = 120 ft. By E. O. Hovey.

The shaded portions were discovered by the Pickett Brothers, 1880.

greatly to the attractions of that remarkably picturesque region. It may not be generally realized that, within a radius of ten miles from those famous springs, are the Garden of the Gods, Glen Eyrie, Monument Park, Pike's Peak, and the Cheyenne, Queen's, Williams Canons and the Ute Pass, with its sparkling "Fontaine qui Bouille," and Rainbow Falls; added to which now the wonderful caverns, which it is my object to describe in this article.

I shall first mention "The Cave of the Winds." This name was long given to an open cleft in the limestone wall of Williams' Canon, rather more than a mile distant from the soda springs of Manitou. It is under the cap of the mountain, and some distance above the roadway. Williams' Canon is very narrow, and its almost perpendicular walls vary in height from 200 to 500 feet. Hence it is not remarkable that this rift should have remained so long unexplored. It looks from below like the mere beginning of a new canon to intersect the main one. It is about ten feet wide and seventy feet high, and spanned by a double natural bridge. A small orifice was discovered within this rift, in 1880, by two boys named Pickett. This let them into three rooms, which they explored. This part of the cave is shaded on the map. The property belonged to Messrs. Reinhart & Snider, of Manitou, who promptly took possession of the new discovery. In January, 1881, Mr. G. W. Snider, who seems to have a fondness for cave hunting, forced an entrance by drill and hammer through a seam in the limestone,

that led to the discovery of perhaps thirty more rooms. The names of the various halls and chambers are not given on the map, owing to some confusion in the naming as furnished to me. They have, however, little scientific significance. The Cave of the Winds boasts an unusual growth of stalactites and stalagmites, besides satin spar, helictites, oolopholites, Epsom salts, and various other minerals such as are commonly found in limestone caverns. Extensive beds of ocher, in certain avenues, show that the subterranean stream that once flowed here, brought down from the granite hills above, decomposed feldspathic materials for these ferruginous clays, which are now hard enough to take a fine polish. Beds of rounded pebbles also occur, often coated by stalagmitic deposit. These have been by some referred to the time when the ocean washed the foot of Pike's Peak. But there has been time enough since then for the running water to cut out the whole cave; and the same agent probably rounded the fragments of granite into these pebbles. The cave in its present condition is very dry, with few standing pools.

The accompanying map, drawn by my son, Mr. E. O. Hovey, from data supplied by Mr. G. W. Snider, is as correct as anything to be had. It is on a scale of 120 feet to the inch. Accordingly, the areal dimensions of the Cave of the Winds cannot well exceed 660 feet in its longer and 300 in its shorter axis. The visitor fol-

1. Entrance. 2. Vestibule. 3. Canopy Av. 4. Alabaster Hall. 5. Horseshoe Tunnel. 6. Narrows. 7. Lake Basin. 8. Jumbo Tunnel. 9. Rotunda. 10. Music Hall. 11. Lake. 12. Organ. 13. Lovers' Lane. 14. Bridal Chamber.

PLOT OF MANITOU GRAND CAVERNS.

Scale, 1 in. = 120 ft. Surveyed by J. Robinson.

The solid line represents the contour of the floor; the curved dotted lines represent the horizontal sections of rooms wider above the floor; the straight dotted lines are the surveyor's lines.

lowing the paths and rambling around through the galleries would no doubt walk a mile or two. Only about twenty rooms are really exhibited, the remainder being difficult of access.

We shall next visit the Manitou Grand Cavern. To do so we follow the well-worn road winding up the Ute Pass. On the right are granite cliffs, and on the left the gorge through which flow the waters of Fontaine qui Bouille. We pass the lower falls, or Baths of Venus, and then shortly reach the famous Rainbow Falls, one of the most beautiful cascades in existence.

At a point about 200 yards above the falls, the carriage road leads up Cavern Canon, to Cavern Mountain—a mass of red and gray limestone, whose fossils show that, like the limestone of Williams' Canon, it belongs to the Silurian period. From the door of the cavern itself a magnificent prospect greets the eye, including high cliffs and foot hills, while in the distance the snow-capped summit of Pike's Peak is visible. This opening was discovered by Mr. G. W. Snider, in 1881, but the caves were not exhibited to the public till 1885. There were 10,000 visitors in 1886, and a still larger