sion of the observations made with the meridian photometer during the period 1882–88. The magnitudes, as given in the "Harvard Photometry," are compared with both the "Uranometria Argentina" and the *Bonn Durchmusterung*.

For the greater part there is close agreement, but the magnitudes in the *Bonn Durchmusterung* are found to have a systematic variation according to the right ascension, the stars grouped at about R.A. 7h., in the Milky Way near Monoceros, being more affected than others also in the Milky Way, but at R.A. 18–19h., in Aquila.

Part of the differences between the "Harvard Photometry" values and those of the "Uranometria Argentina" are ascribed to the difference in position of the two stations, as the zenith distances of the stars would be different, and therefore, presumably, the atmospheric absorption; no correction being applied for this, the southern stars at Cordoba would be estimated too bright.

An attempt to revise the scale of the *Durchmusterung* decided that it was practically impossible to reduce it to the photometric scale by any simple rule, and for purposes of comparison the necessary corrections are given to convert one scale into the other from magnitudes 1·0 to 9·2.

Pages 185–233 are devoted to a discussion of the relation between the magnitudes in the *Harvard Photometry* and those determined by Sir William Herschel. Of the six catalogues of Herschel's observations, the third is considered more accurate, and the fifth less so, than the others. In all he published observations of 3000 stars, and the *average* difference from the photometric catalogues of the present day is only $\pm 0{\cdot}16$ magnitude, this including both the possible change during the century which has elapsed and the errors of both determinations. Prof. Pickering is surprised that these observations should not have been repeated at intervals of ten or twenty years, so that deviations of individual stars might be detected. With this idea he gives a special table including all stars in which the difference between Herschel's magnitudes and the photometric ones equals or exceeds half a magnitude.

The remainder of the volume, pp. 234–245, deals with investigations in regard to the relative performance of the large and small meridian photometers which have been employed in the production of the *Harvard Photometry* itself. No difference exceeding the hundredth of a magnitude was detected. Tables are given showing that the values of the *Harvard Photometry* are not sensibly affected by variations of magnitude, right ascension, declination, or proximity to the Milky Way.

TORSION-STRUCTURE IN THE ALPS.[1]

ONE of the most brilliant and suggestive chapters in Suess' monumental work "Das Antlitz der Erde" is that in which he deals with the remarkable whirl-shaped arrangement of the leading lines of the Alpine system (vol. i. chap. 2).

Prof. Suess describes how the "leading line" sweeps round the north in one great curve convex to the north, the Apennines describe a curve convex towards the east, whereas the Dalmatian mountains form opposite it a curve convex to the west; and the curve of the Apennines is continued westward along the Algerian ranges of North Africa, whereas the Dalmatian curve is continued eastward towards Asia Minor. Prof. Suess points out that movements of crust-folding have always taken place towards the convex or outer side of these curves, and have in most cases caused an actual transgression of the curves above the regions in front of them. He further states that it is not fully understood why the mountain-systems should follow curved lines, or why the curves of the Alpine upheaval should in many areas repeat those of former mountain-systems.

Let me, before going further, remind the reader of a lecture given by one of the greatest of stratigraphers, Prof. Lapworth, at a meeting of the Royal Geographical Society five years ago, and reported in these pages ("The Face of the Earth," NATURE, April 26, 1894). This lecture set forth the conception of crust-torsion, demonstrating that "like the present surface of a typical geological formation . . . the surface of the earth-crust at the present day is most simply regarded as the surface of a continuous sheet which has been warped up by the two sets of undulations crossing each other at right angles. But in the case of the earth-surface, the one set of undulations ranges parallel with the equator, and the other ranges from pole to pole."

Prof. Lössen's explanation of the involved stratigraphy of the Harz mountains lays the foundation of our knowledge of torsion phenomena in the field, and, although other explanations have been given of the special difficulties in the Harz mountains, Prof. Lössen's is now generally accepted.

When working out the detailed stratigraphy of a part of the Dolomites, I experienced the same difficulties which Prof. Suess had indicated in connection with the "whirled lines" of the Alpine system generally. My results were laid before the Geological Society in December 1898, and are now published in the August issue of the *Quart. Journ. Geol. Soc.*, along with a stratigraphical map of the district examined. In that paper I have tried to show that the possible solution of some of the difficulties lies in the association of torsional movements in conflicting directions through the crust, with movements of crust-folding taking place across a pre-existing set of crust-folds. The *change in the direction of the resultant earth-thrust* is the cause to which I have ascribed the torsional phenomena observed in the crust-folds.

The following notes will indicate as briefly as possible wherein the characteristic features of Sella and Enneberg in the Dolomites are analogous with characteristic features of the Alpine system, and how far the elucidation I have offered for that area on the lines of torsion may be capable of a wider application.

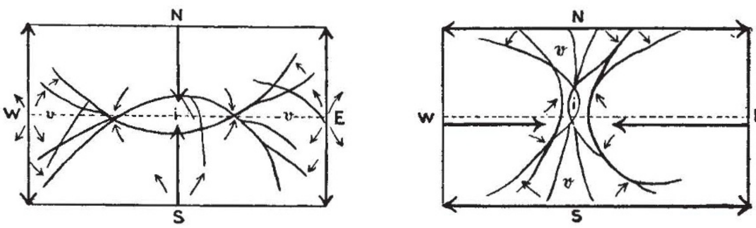

FIG. 1.—Formation of fold-arcs under the influence of torsion-forces. *i*, areas of interference; *v*, areas of virgation.

The stratigraphy of Sella and Enneberg is characterised by twisted strikes, twisted cleavages, twisted arches, twisted troughs, twisted faults, twisted dykes and sills—in fact, the rocks have been twisted and sheared to such a degree that thick deposits have been twined into the form of rock-whorls and large masses of limestone for the greater part changed to dolomite. The various combinations of twisted strikes produce the effect of "whirled" stratigraphical lines round individual centres of the region examined. Sigmoid curves in one direction are correlated with sigmoid curves in another, and arcs which are convex towards north and south are connected by virgating lines with arcs which are convex towards east and west.

Thus we may say that the curves round the north, east, and south of the Sella mountain resemble the "whirl-shaped leading lines" of the Riviera Alps, Apennines and Algerian mountains round the western basin of the Mediterranean Sea; while the curves round the north, west, and south of the Prálongia and Sett Sass area resemble the whirl-shaped lines of the Dalmatian and Pindus mountains and the curvature through the eastern basin of the Mediterranean Sea. The latter curvature resembles that of the mountains around the Roumanian plain, or of the Alps round the plain of Piedmont.

Examples might be multiplied interminably, and on great and small scale, *the reason being that the essential structure of the Alpine system is based upon spirally twisted folds, and not upon linear anticlines and synclines.*

The formation of fold-arcs is illustrated in the accompanying diagrams (Fig. 1), which show that the action of one torsion-couple must be compensated by the reverse action of a correlated torsion-couple, and a fold-arc convex towards one compass direction must be coordinated with a fold-arc convex towards the opposite compass direction. When the convexities approach one another during torsional movements the result is that oppositely-curved fold-arcs intertwine in an area which may be

[1] Condensed from the concluding chapter, "Application to the Alps," in a paper presented at the Roy. Geol. Soc., December 1898.

termed an area of "interference," to distinguish it from the areas of "virgation" where fold-arcs curve away from one another.

A fold-arc is not a homogeneous fold, but is made up of a series of unit-folds, each of which is the segmental portion of a curve. Any one fold, as it were, dies out in its particular direction and horizon, but is replaced by a fold in the next part of the curve passing through slightly different horizons of the crust. Thus the arc round which a series of unit-folds is arranged comes under the category of curves that change their plane.

In Enneberg, series of fold-arcs with their convexities towards different compass directions have been overcast, and the overcast folds have been penetrated by reverse and normal fault-planes, reverse movement having taken place in the subjacent slices of the overcast folds. But, combined with reverse movements in virtue of vertical components, there have been converse movements in virtue of torsional components, so that the actual resultant movement has been spiral—*e.g.* while the middle or "arch" slice of an overcast fold moved in clockwise direction and outward, the upper and under slices of the same fold moved in counter-clockwise direction and inward.

The problem resolves itself into involute and evolute movements of crust-slices with reference to central areas, the evolute slices tending ever to spread, the involute slices ever to narrow.

Shear-breccias and fragmentary portions of folds fill up the inwardly-tilted troughs. The fault-rocks in certain of the sheared and twisted troughs of Enneberg had been formerly treated as independent zones of rock, and termed "Buchenstein Agglomerate"; but in my paper they are shown to be practically a "Flysch conglomerate," formed during the Tertiary epoch of Alpine upheaval.

The "Flysch" troughs which appear round the Alpine curves may possibly be explained as the result of similar processes of involute and evolute movements going on in slices of closely-piled overcast folds. Thus we might have troughs being twisted inwards and gathering "Flysch" in variable fragments, while evolute slices of the reciprocal arches were being twisted outwards. The "Klippen," and even the "Klippen" ranges, may represent such "arch" wedges of fold-arcs originally closely piled and jammed as the fold-arcs are round the dolomite massives.

There is abundant evidence in Enneberg that the molten layers immediately below the crust have shared in the movements of torsional-folding. They have filled the body of the virgating fold-arcs produced by these movements, and have there been incorporated in the local crust-whirl of torsion-movements, finding inlet into the planes of fold-shearing, and being dragged and twisted along with adjacent fault-blocks. An inrush during earlier phases of torsion has been in its turn invaded by the next inrush, and so on, in accordance with the gradual progress of torsion; the latest invasions occur along transverse and oblique faults, belonging to a system of faults which has affected Oligocene strata in the Judicarian area; hence such injected rock is not older than Middle Tertiary.

The fundamental feature of torsional folding may be said to be centralisation; whether it be involution of certain horizons in covered troughs, or evolution of other horizons in overcast arches, the movements have reference to the centres of torsion-basins and torsion-buckles.

The principles thus demonstrated in Enneberg will be seen to involve the "fan-shaped structure" of central massives. They could not fail to do so, since they have been deduced from the stratigraphy of Sella massive in Enneberg, which presents a wonderfully symmetrical, although obliquely elongated example of "fan-structure."

I have shown in my paper on Enneberg that the transverse faults define a later or Tertiary series of arches and troughs, through whose septal portions they chiefly pass. The faults are shearing-planes, and are the result of oppositely-directed movements of twisting and thrusting which have taken place from opposite arches upon common reciprocals, the intermediate troughs. These movements have produced the virgating groups of north and south fold-arcs which meet the east and west fold-arcs, and the sigmoidal combinations of torsional fold-arcs and fault-curves represented in Fig. 2.

The continuance of the faulting during a protracted period of crust-adjustment has caused displacement of the arcs on the opposite sides.

There are several well-known lines of tranverse and oblique shearing through the Alps which repeat these phenomena on a larger scale, and at the same time no detail is wanting in the comparison. Some of these may be indicated: (1) The Judicarian-fault; (2) Iseo-Ortler; (3) Como-Sonthofen; (4) Maggiore-Sargans; (5) Tarentaise-Thun; (6) Savoy-Freyburg—all these represent directions of inthrow and faulting along the "septum" or "middle limb" between great transverse arches and troughs which form part of major Alpine torsion-curves.

With regard to the eastern Alps, there are also well-marked N.N.E.-S.S.W. directions of faulting and displacement. The pre-eminent example is the remarkable series of down-throws at the eastern limit of the Alps, with which is associated the displacement of the northern curve of the Alps towards the Carpathian curve. At the same time, the influence of the co-ordinated torsional movements round the Hungarian basin is evidenced in the eastern Alps by N.N.W.-S.S.E. directions of transverse-shearing.

All the transverse directions of tectonic disturbance in the Alps have in common with the parallel Enneberg lines (*a*) the

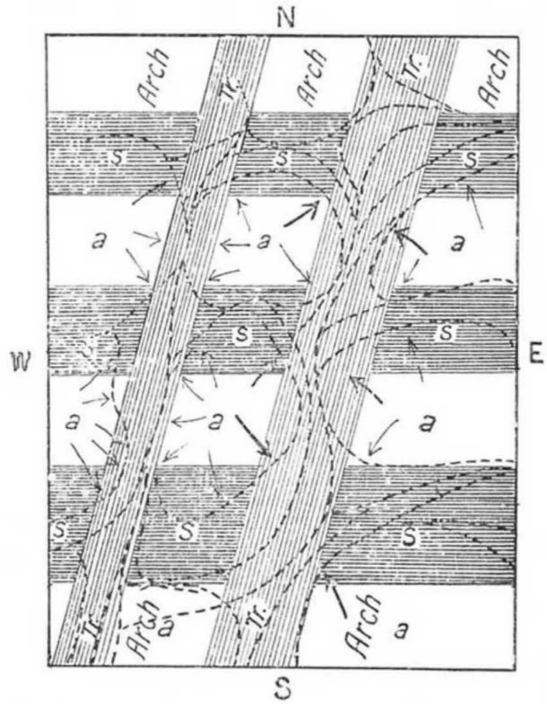

FIG. 2.—Superposition of a later series of arches and troughs upon an east and west series (a, s); chief result, overcasting and overthrusting of old and new arches over synclinal troughs. - - - - fold-curves and faults formed by the twisted shearing.

virgation from them of an eastern and western series of torsion-curves, representing fold-arcs; (*b*) the injection of igneous rock along the main direction of "septal" shearing, associated with the presence of larger masses in the areas of fold-expansion; (*c*) the fact that they have continued to act as lines of crust-adjustment subsequently to the period of acute torsional upheaval. In the Alps the repeated displacement of the main chain to the north would simply indicate that the arch on the east of any transverse depression had been originally less elevated than the arch on the west of the same depression. The extent to which eastern curves have been twisted away from western curves originally belonging to the same "bundle" of virgating folds, may give us some idea of the tremendous shearing that has taken place, and the great compression that the Alpine regions have sustained from east and west in virtue of this oblique, sigmoidal movement of opposite arches over intervening synclines (Fig. 3).

The law which I deduced from my observations at Sella was that the southwardly-convex torsion curves are marked by overthrust of the folds towards the south, the northwardly-convex curves by overthrust of the folds towards the north. This law agrees with the movements which Prof. Suess has described along the curved lines of Alpine upheaval, and finds further confirmation in the curious effects of reversal of thrust-movements which are so highly characteristic of all the great transverse Alpine arches. To cite one example, compare the great overthrusts round the south curves of the western Alps with the northwardly-directed overthrusts in the Bernese Oberland.

The drawing (Fig. 3) shows that the eastern and western fold-arcs associated with any transverse direction of faulting provide the same fundamental conditions of peripheral overthrusts with reference to definite centres which I demonstrated in Enneberg. And as the centres are comprised in the very highest transverse Alpine arches which were determined during the later epoch of Alpine upheaval, it is here that, according to torsional laws, the highest individual massives should be present.

The essential structure is the same, whether it be exemplified in the variously-shaped dolomite massives or in the variously-shaped central massives—elliptical, lenticular, or elongated, clearly or less clearly defined from one another—all may be regarded as an inevitable result of crust-torsion.

Even when considerable subsequent faulting and lateral displacement might seem to have obliterated the original relationship of opposite torsion-curves, there are long streaks or interrupted appearances of igneous injections along the main fault-line, which afford evidence of a probable original connection between eastern and western fold-arcs now fairly remote from one another.

The more or less sickle-shaped form of some Alpine curves represents a north and south fold-arc on the same side of a transverse direction of shearing. The Enneberg curve (Langs-da-Für, Campolungo, Cherz Hill) is an example on a small scale, the Banat curve round the Roumanian Plain is an example on a grand scale.

The chief line of fault there is the "Banat" line, which in its tectonic relations bears a strong resemblance to the Judicarian line. It runs north and south and separates a western area of mica schists from an eastern depressed area of Jurassic and Cretaceous strata, eruptive rocks occurring at intervals along the fault. In describing the Banat fault, Prof. Suess never doubts the Tertiary age of the folds and of the eruptive rocks associated both with the folds and with the fault. He notes the twisting character of the strike, and expressly states that the eruptive rocks "*must have been Tertiary notwithstanding the resemblance almost amounting to identity which they present with those of the Judicarian and Predazzo areas* ("Antlitz," i. p. 623 and pp. 210-213; the italics are mine). Further, he quotes Dr. Posepny's opinion "that these eruptive masses are not masses exerting pressure, but themselves pressed. The subsidence of a neighbouring district induces such eruptions, but the eruptive masses themselves are pressed into the dykes by the pressure of the sinking masses" (*l. c.* p. 210). Similar reasoning was followed by Dr. Salomon in his paper on the Peri-Adriatic eruptive masses, wherein he advocated the theory that the Peri-Adriatic masses originated in consequence of the Peri-Adriatic subsidence, and were of the age of the subsidence.

I would be inclined to class both the Judicarian and Banat faults as phenomena of torsional eruptivity which may, upon the evidence of the sedimentary strata involved in the folds, be referred to the Mid-Tertiary epoch of Alpine upheaval.

Two great internal torsion-basins within the Alpine systems of southern Europe are the Hungarian and the west Mediterranean. The arrangement of the Carpathian mountains round the Hungarian basin presents all the characteristic features of torsion. Mountain fold-arcs have formed peripherally, and broken arches have been thrust outwards and upwards from the basin, while fold-slices produced by normal faulting have had an involute movement inward and downward. Eruptivity has been particularly active in the main septal zone between the oppositely moving portions of the fold-arcs. The Dalmatian mountains represent a series of peripheral folds whose arches have moved towards the south-west, while the eastern Alps betray the influence of this movement of folding, and also a co-ordinated movement to north-west.

The centrifugal movements round the periphery of the western part of the Mediterranean basin have caused the up-folding of the Apennines towards the north-east, and again an igneous zone runs irregularly between the area of peripheral out-thrust and inward down-throw. It is still further within the igneous zone that we must look for the buckling-up of new rock-folds, but the new folds can never be absolutely parallel with the predecessors, *since crust-torsion is going on all the time.* Hence the virgation of successively formed ranges in great mountain-systems would appear to rest upon much the same principle as the virgation of fold-arcs illustrated at Gröden Pass in Enneberg (*Q.J.G.S.*, August 1899, *l.c.*, Plate I.).

While torsion-basins tend by reason of repeated buckling to narrow within themselves, the tendency of the regions outside the outermost peripheral fold-arcs is to subside towards the torsional sag. To such return involute movements we may probably attribute the present subsidence going on in the Adriatic areas, as also the tendency for lakes and plains to form on the outer skirts of torsional mountain-systems.

The Caucasus mountains afford an example of the occurrence of an internal area of down-throw in various parts of which

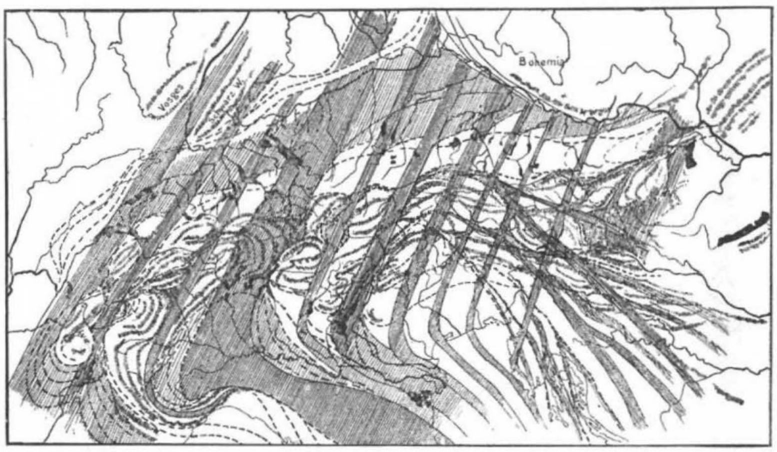

FIG. 3.—The leading oblique arches and troughs of the Tertiary upheaval of the Alps. (The troughs are shaded, the arches are between the troughs, and the chief fold-arcs of the mountain masses are indicated within the arches by shading and broken lines.)

vulcanicity has been active, and of outer areas along which overcast folds of immense size have been gradually involuted. The Alps show at the present day an advanced phase in their torsional history. Earlier outer folds have been broken down owing to dynamic as well as aërial causes of denudation, and have disappeared along interrupted outer shear-zones which I would identify as those occupied by "Flysch" rocks of whatever age. These rocks represent the necessary deformation of older and less twisted folds by the process of involution during the gradual evolution of later and more twisted folds.

Such an explanation of the relation of the Flysch to the present Alps would agree with the observed fact that fragments of granitoid and metamorphic rocks contained in the Flysch show less metamorphic change than those in the central massives of the Alps, since it would relate the Flysch to lost earlier folds which had undergone a smaller degree of torsion than the succeeding folds.

The widely-extended subsidence during Jurassic and the greater part of Cretaceous time in Europe seems to have been the turning-point in the history of Alpine upheaval, since previously, in Alpine regions, the resultant forces had acted more strongly from north and south than from east and west, and afterwards the movements came almost transversely. Hence the long continuation of the great Mesozoic epoch of deposition and subsidence, in inducing the strong action of east and west crust-strains over a region where previously the action of north and south crust-strains had been pre-eminent, has probably been the initiative cause of an acute epoch of crust-torsion and folding along oblique and transverse lines.

The new movements affected all European areas, dovetailing new folds into the midst of, and across, old folds, and determining new centres of virgation. In the Alps new arches and troughs were formed obliquely and transversely across the older series; the first-formed basins in the new movement were themselves over-arched or blocked up as the fan-shaped mountain-massives gradually became more and more compactly pressed together, and the great torsion-basins of southern Europe became confirmed in their new shape and position acquired in accordance with the altered conditions of crust equilibrium.

As might be expected, there is frequent indication that eruptive activity in Tertiary time broke out afresh in the same areas where eruptive activity had marked the Upper Carboniferous and Permo-Triassic period of movements. But the chief groups of eruptive rock round the inner *curves* of the Alps, Apennines and Carpathians, as well as the injections along oblique directions of shearing, may be clearly identified with the Tertiary torsion movements, for the most part, with the acute Mid-Tertiary epoch of torsion. The larger masses of igneous rocks in the central massives may belong in part to the ancient Palæozoic or Permo-Carboniferous epochs of upheaval, in part to the late-Mesozoic and Tertiary epochs.

A general conclusion may be made from the above that there are serpentines, diorites, granites, felsites, basalts in Alpine folds and faults which can be identified more especially with the "evolute" phenomena of Tertiary torsional movements. And these intrusions, injections, and eruptions involved in the last acute epoch of upheaval in Southern Europe are clearly correlated with similar eruptive phenomena throughout the same period in other parts of Europe, *e.g.* Auvergne, Scotland, Iceland.

MARIA M. OGILVIE.

THE MOTION OF A PERFECT LIQUID.[1]

IF we look across the surface of a river, we cannot fail to observe the difference of the movement at various points. Near one bank the velocity may be much less than near the other, and generally, though not always, it is greater in the middle than near either bank. If we could look beneath the surface and see what was going on there, we should find that the velocity was not so great near the bottom as at the top, and was scarcely the same at any two points of the depth. The more we study the matter, the more complex the motion appears to be; small floating bodies are not only carried down at different speeds and across each other's paths, but are whirled round and round in small whirlpools, sometimes even disappearing for a time beneath the surface. By watching floating bodies we can sometimes realise these complex movements, but they may take place without giving the slightest evidence of their existence.

You are now looking at water flowing through a channel of varying cross section, but there is very little evidence of any disturbance taking place. By admitting colour, although its effect is at once visible on the water, it does not help us much to understand the character of the flow. If, however, fine bubbles of air are admitted, we at once perceive (Fig. 1) the tumultuous conditions under which the water is moving and that there is a strong whirlpool action. This may be intensified by closing in two sides (Fig. 2), so as to imitate the action of a sluice gate, through the narrow opening of which the water has all to pass, the presence of air making the disturbed behaviour of the water very evident.

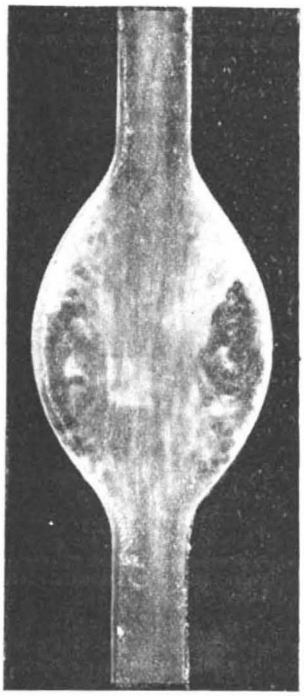

FIG. 1.

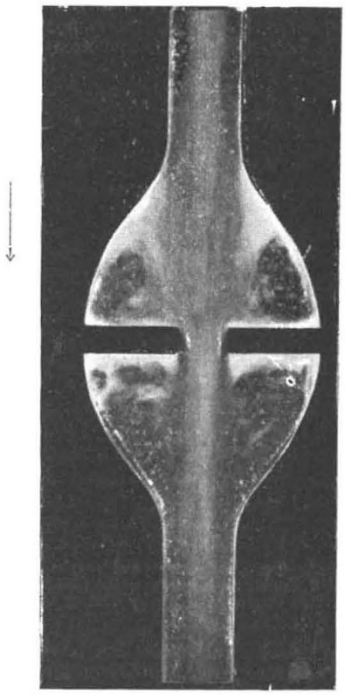

FIG. 2.

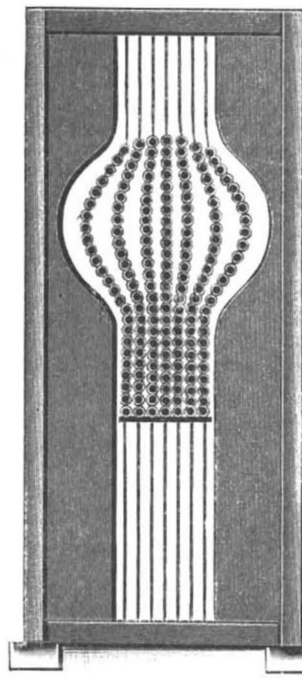

FIG. 3.

Now you will readily admit that it is hopeless to begin to study the flow of the water under such conditions, and we naturally ask, are there not cases in which the action is more simple? Such would be the case if the water flowed very slowly in a perfectly smooth and parallel river bed, when the particles would follow one another in lines called "stream-lines," and the flow would be like the march of a disciplined army, instead of like the movement of a disorderly crowd, in which free fights taking place at various points may be supposed to resemble the local disturbances of whirlpools or vortices.

The model (Fig. 3) represents on a large scale a section of the channel already shown, in which groups of particles of the water are indicated by round balls, lines in the direction of flow of these groups (which for convenience we may call particles) being coloured alternately. When I move these so that the lines are maintained, we imitate "stream-line" motion, and when, at any given point of the pipe, the succeeding particles always move at exactly the same velocity, we have what is understood as "steady motion."

[1] A discourse delivered at the Royal Institution on Friday, February 10, by Prof. H. S. Hele-Shaw.