From crystals of the salt prepared as above mentioned,

I. 1·2864 grm. gave 1·3203 grm. chlorid of silver.

II. By leading dry hydrochloric acid gas over glycocoll in the manner already described, a compound was formed, of which,

1·1370 grm. gave 1·1845 grm. chlorid silver.

In per cent. expressed, these determinations give,

$$3(C_4\ H_4\ NO_3)+2HCl+HO,$$

which requires 25·30 per cent. of chlorine. As the probable rational constitution of the above salt the following is submitted,

$$(Gl\ HCl+Gl,\ HO)+Gl\ HCl.$$

Anhydrous Hydrochlorate of Glycocoll.

Having found a basic hydrochlorate, which might be regarded as a double salt of one atom of hydrate of glycocoll, with one atom of anhydrous hydrochlorate of glycocoll:

$$C_4\ H_4\ NO_3,\ HO+C_4\ H_4\ NO_3,\ HCl,$$

and especially having found as will be seen below, an anhydrous *sulphate* of glycocoll, it was natural to suppose that the anhydrous hydrochlorate might be obtained by itself, viz. $C_4\ H_4\ NO_3,\ HCl$.

To this end absolute alcohol was saturated with hydrochloric acid gas, and this added to a solution of glycocoll in hot spirits of wine. Upon evaporating the liquid, delicate prismatic crystals appeared which deliquesced with the greatest rapidity. They even dissolved in absolute alcohol. This latter circumstance led to the supposition that the crystals might have been a double salt of hydrate of glycocoll with hydrochlorate of oxide of ethyle. This supposition was further strengthened from an analysis of a sulphate of corresponding constitution soon to be noticed.

(To be continued.)

Art. XXXIX.—*Origin of the Grand Outline Features of the Earth;* by James D. Dana.

The traveller who follows along the indented shores of a continent, or, traversing the ocean, touches here and there at an island, is likely to become strongly impressed with the common idea that the land has every where the utmost irregularity of form, and that islands are "scattered dots" over the wide seas. Such must be the conclusion of any one who should judge from his own casual observations. Were there a system in the world's physiognomy, it could not become apparent till explorations had traced accurately the varying outlines and elevations of continents, and the positions of islands. A good map or globe is a register of the thousand observations of voyagers and surveyors upon these points. It is a miniature of the world within the grasp of our view, and may be properly appealed to with reference to the earth's features. The evidence has not been overlooked by the philosophers of the day, and is more or less fully discussed by Humboldt, Malte Brun, L. A. Necker, Elie de Beaumont, Boué, and other geographers and geologists. Yet it has failed of fixing general attention. It is proposed to pass briefly in review the principal facts, and consider the causes to which the existing features of the earth are attributable.

The remarks which follow will be hardly intelligible to the reader without a globe before him, or a Mercator's chart of the world: and the latter, though the best kind of map for the purpose, is somewhat erroneous in consequence of the parallelism of the meridians.

Trends of Coasts and other Features of Continents.—1. On the continent of America, the reader will observe the nearly straight coast line from the Gulf of Mexico along by Newfoundland and Greenland, a distance of 5000 miles; the near parallelism of this line with the southeast coast of South America, 4000 miles in length; also with the line of Lakes Ontario and Erie, and the river St. Lawrence; also with the coast on the northwest of Hudson's Bay, and that by Prince Regent's inlet. These parallelisms are too striking not to be at once obvious. They are instances of a *northeast* and *southwest* trend; and the distance between these great parallel lines are respectively about 3000 miles, 250 miles, 1400, and 380 miles.

Again: look at the west coast of the same continent, from Darien to Russian America, and laying down a rule, mark the near parallelism of the course with the line of great lakes, from Erie through Michigan, Superior, Winnipeg, Slave and Bear, to the coast by the mouth of the Mackenzie; also with the southwest side of Hudson Bay; with the coast on the west of Davis Strait and Baffin Bay, and that also on the east. Here the uniformity is even more remarkable. These are instances of a *northwest* and *southeast trend.* To one of the two lines correspond the greater part of all the grand features of the continent. The apparent exceptions will be hereafter considered. The distances separating these *northwest* lines average respectively 1000 miles, 350, 700, and 400 miles.

2. Compare the sides of the Atlantic Ocean. The southeast coast of South America, from Magellan to St. Roque, is almost an exact continuation of the western line of the opposite continent, by western Africa, Spain, and Norway or the Baltic; and the break in the line made by the Atlantic, is partly filled by the islands Fernando Noronha, St. Paul and the Cape Verds. It will be shown hereafter that the northeast coast of South America belongs to the northwest system of trends, and extends by Guatemala and California northward; and if we cross the ocean,

we find the Cape Palmas coast of Africa, or rather the Kong mountains adjoining, and the Pyrenees between Spain and France, having the same trend as the northeast of South America.

3. In the eastern continent, the western coast of Europe and eastern of Africa have a striking parallelism, in which the north coast of Asia, from the Obo Gulf to the northeast cape, partakes; and so also the east coast of Asia, the east coast of Hindostan, and also the island of Madagascar. These are *northeast* trends. Again, we observe that the Red Sea, Adriatic and British isles, the Persian Gulf, Western Hindostan, and the coast from Calcutta by Malacca, are nearly parallel lines, having the *northwest* trend. Whatever may be said of the exceptions and irregularities, there are evidently too many coincidences to be set aside as mere accident; and the two courses have accordingly been considered by Humboldt, the great geographical lines of the globe.

We might pursue the same course with the mountains. But the general parallelism of the chains with the coast lines, is so obvious that we barely allude to them in this brief outline of the subject under discussion. The fact is plainly true with respect to the great chains of America: and some particulars, soon to be stated, will bring into one system what appears irregular in Europe and Asia. We observe only that Tchihatchef, a Russian traveller, has pointed out the conformity of the main range of the Altai to the course of the east coast of Africa and the island of Madagascar, while there is also a northeast range in the same chain, parallel with the Persian Gulf and Red Sea: the highest point of the Altai mountains occurs at the intersection of the two ranges.*

Trends of Groups of Islands.—We proceed to a few remarks on the islands of the ocean; and they are the more satisfactory, as islands are the culminant peaks of submerged mountain chains, and therefore mark correctly the proper outline features of the earth's surface. The fact that the islands range in lines was long since pointed out; and Malte Brun remarks on the regularity of these lines in the Pacific Ocean. Compare the line in which lie New Ireland, the Salomon group and the New Hebrides, with the Sandwich or Hawaiian range, extending to the northwest through a number of small islets 2000 miles, from longitude 155° W., beyond 180°. Though 3500 miles apart, the lines are nearly parallel; and parallel also with New Caledonia, and with northeast New Holland, on one side, and nearly also with the coast of California and Guatimala on the other; and moreover, these lines are

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* Comptes Rendus, May 12, 1845. Tchihatchef observes that the occidental chain runs N. W. and S. E., and the other or oriental, N. E. and S. W. He mentions that a similar system exists in the Alps; but as the identity of direction is not exact, he considers the two systems different.

parallel with the several intermediate chains of islands, as is apparent on the largest charts: the details which are highly interesting will be given by the writer in his Geological Report on the Pacific. Here, then, is an approximate parallelism in ranges over more than a quarter of the circumference of the globe; and nearly all correspond to the *northwest* trend. New Zealand and the Tonga group, and the Ladrones, are examples of the transverse or *northeasterly* trend. The latter trend, (approaching N. N. E.,) characterizes a part of New Holland, the Australian Alps of the southeast, and as observed by Fitton,* the west coast of the Gulf of Carpentaria and the islands off its north cape; besides, also, the northwest coast: the inlets of the coast correspond almost uniformly to one of the two courses pointed out. The Galapagos illustrate distinctly both trends, and they are so mentioned without alluding to any general law, by Darwin.† Beyond the American continent, in the Atlantic, we find the Azores closely parallel with the Hawaiian line; and the same is illustrated in the Canaries, according to the position of the islands given by von Buch,‡ and also in the Cape Verds. These lines are also parallel with northeast South America, and the Pyrenees. Thus, not only over one ocean, but over both, the same system prevails, and alike also over the intermediate continents, the one corroborating the other. The system in truth belongs to the world. To this conclusion Humboldt, Necker, Boué, and other geologists appear to have arrived.

But if we survey the facts more minutely, may we not find that an element in this branch of physical geography has not been properly apprehended? Do not the exceptions throw in a vexatious doubt, if they cannot be blended with the theory? We propose, then, to pursue the subject still farther; and we believe that instead of proving that there are as many distinct systems in orography as there are mountain courses,§ it will

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* Sketch of the Geology of Australia, Phil. Mag., 1826, lxviii, 18, 132. The regular lines of islands were observed by Flinders, as remarked by Fitton, (ibid., p. 132.) See Flinders's Voyage, ii, 246.

† Volcanic Islands, p. 115. "Three great craters on Albemarle island, form a well marked line, extending N. W. by N. and S. E. by S.; Narborough island and the great crater on the rectangular projection of Albemarle island, form a second parallel line. To the east, Hood's island and the islands and rocks between it and James' island, form another nearly parallel line; which, when prolonged, includes Culpepper and Wenman islands, lying seventy miles to the north. The other islands, lying further eastward, form a less regular fourth line. Several of these islands and the vents on Albemarle island, are so placed that they likewise fall on a set of rudely parallel lines, intersecting the former lines at right angles; so that the principal craters appear to lie on the points where two sets of fissures cross each other."

‡ Les Iles Canaries, 360. The craters of Gran Canary, Teneriffe and Palma, are in a northwest line, while a transverse trend is distinct in the several islands.

§ Essentially the theory of Elie de Beaumont, in which view he is supported by many distinguished names in geology.

appear more in accordance with facts, to refer even wide deviations of directions to one and the same system.

General character of the lines of Mountains, Coasts, and Islands.—A careful study of the courses of island groups, coasts and mountain chains, leads us to the following important results:—

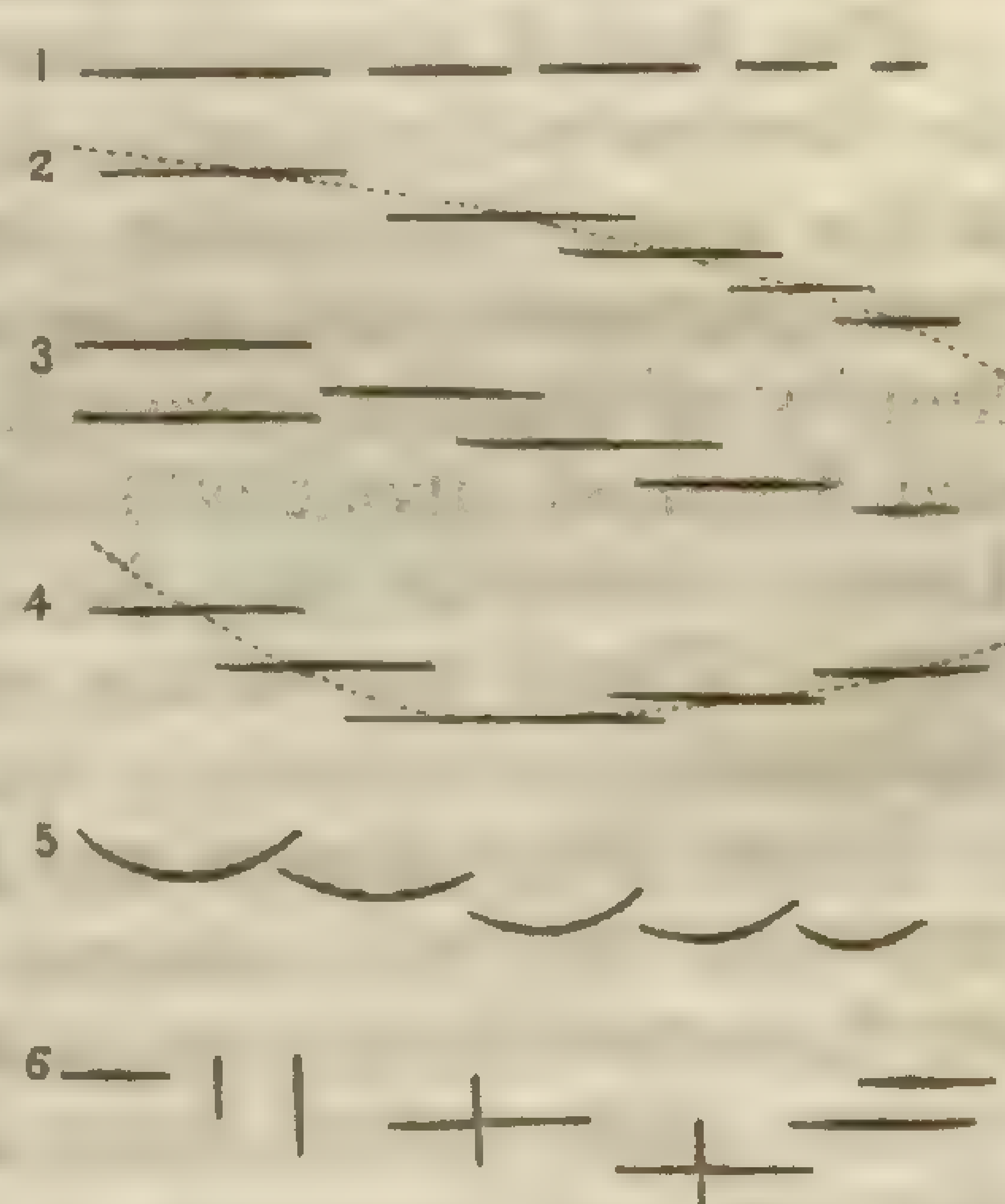
I. *The ranges are made up of shorter consecutive and sometimes parallel lines, instead of being uninterrupted for long distances.*

II. *The ranges are more commonly curved, than straight or coincident with the course of a great circle.*

III. *The straight ranges are generally straight in the constituent lines. but may consist of a series of curves.*

IV. *Curved ranges may arise from a general curvature in the whole; but often proceed from the positions of the several consecutive parts.*

V. *The same range, owing to the mode of curving, may vary greatly in its course, in different portions.*



In these points we are stating merely the facts or results of observation, free from speculation. The following figures may serve to illustrate the propositions stated.

In figure 1, the entire range is straight, as well as the parts.

In figures 2, 3, and 4, the parts are straight and overlap, and thus form a range which is sometimes straight as a whole, but is more frequently curved. The direction of the whole range, as shown by the dotted line, differs from the direction of the subordinate lines.

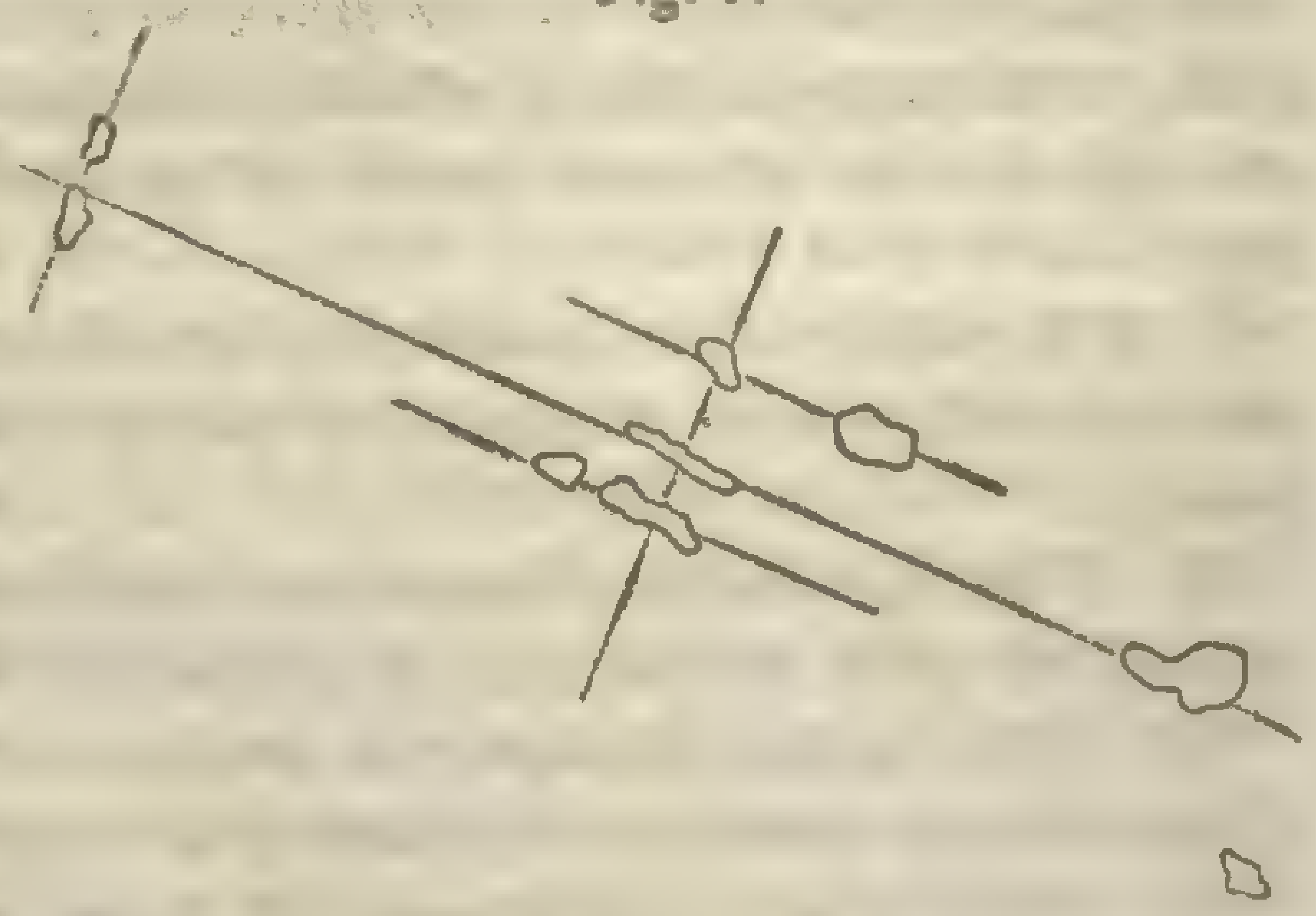
Figures 3 and 7 represent a common condition in which there are parallel lines in some parts of a range.

In figure 5, the parts are curved; and here, too, the resulting range may be straight or curved.

Fig. 6 represents a range made up of longitudinal parts along with some transverse; this is of common occurrence (figure 7.)

The more thorough the examination of the trends of groups of islands and of mountain chains, the more distinctly will this system of things be apparent; and instead of straight lines, or parts of great circles, it will be found that the predominant courses in the earth's features are curves. All these points might be abundantly illustrated by the groups of the Pacific islands; but we omit the details, as the subject will be fully presented in the Report, by the writer, on the Geology of the Ocean. Suffice it to say, that in the Hawaiian range these principles are distinctly represented; so also in the Samoan group, the Kingsmills, the Ladrones, and others.

Fig. 7.



Azores or Western Islands.

The citation from Mr. Darwin, in the note to p. 384, exhibits both parallel and transverse lines in the Galapagos; and in the Canaries there are similar facts. The position of the Azores here given, well illustrates the subject. The main parallel lines are too obvious to require particular remark, and the transverse are also apparent.

A system of curves, on a grand scale, is seen along the east of Asia, resembling figure 5. The reader, to appreciate the facts, should refer to his map, and the best and largest within reach.

The *first* of these curves extends from Kamschatka south by the Kuriles to Yeso, and is 1500 miles long; a *second*, from Yeso, or the island Sanghalian just north, along Niphon to its southwest extremity, 900 miles long; a *third*, from the southwest extremity of Niphon, through Kiusiu and other islands, to Loochoo and Formosa, about 900 miles long; a *fourth*, from Formosa, by Luzon, Palawan and the western coast of Borneo, 2000 miles long. These curves are singularly alike in form and relative position.

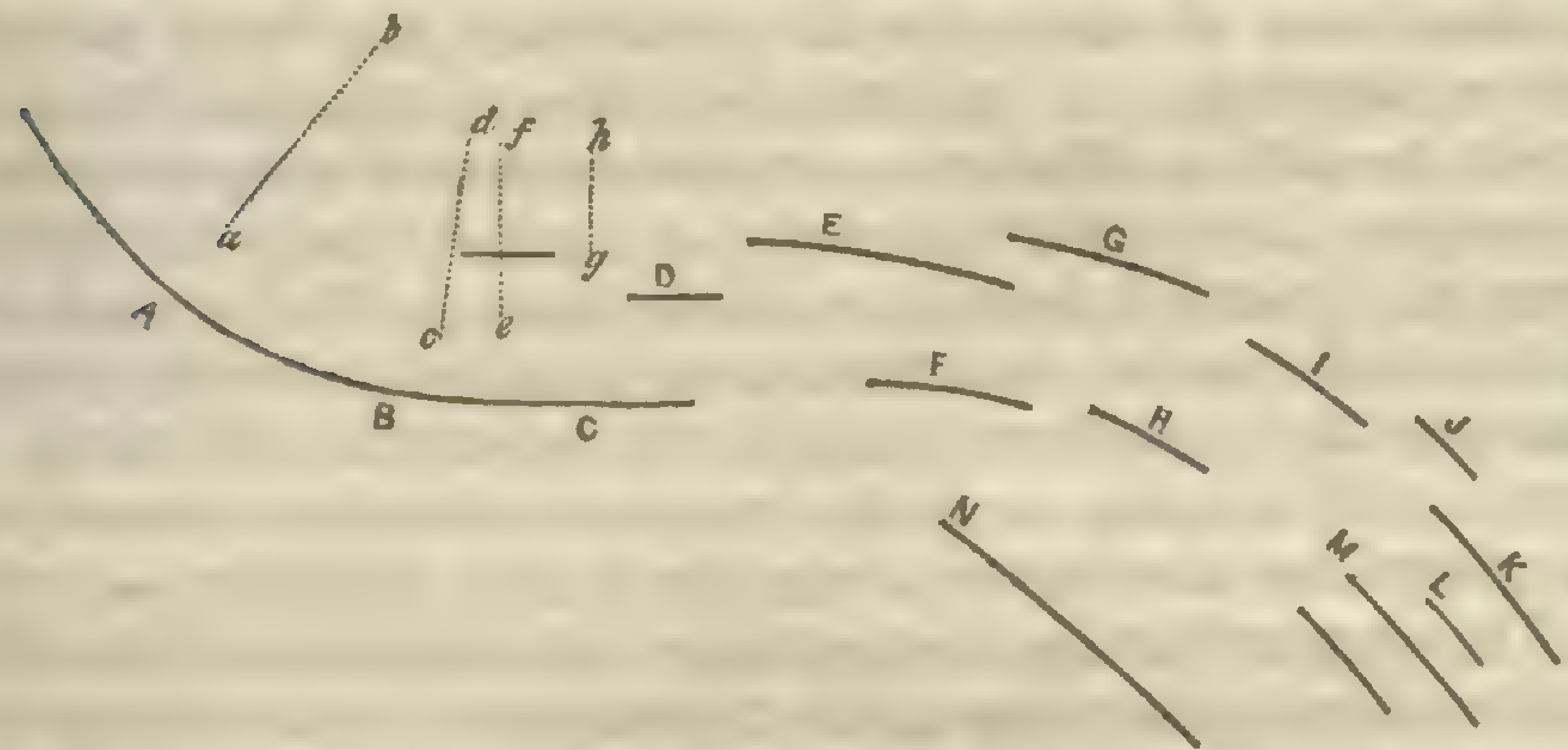
These coincidences are facts: accidental, that is, without a cause, no one will pretend. The Alaschka Archipelago, at the north, seems like a part of the same system; it forms a regular curve, 1600 miles long, between Kamschatka and Russian America.

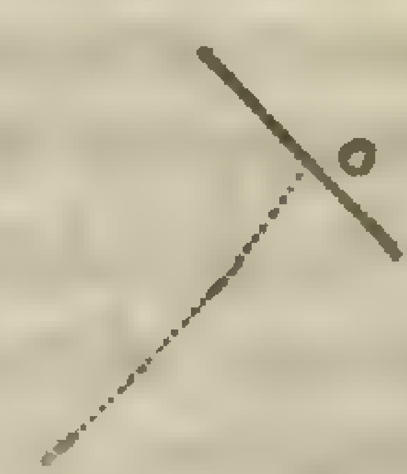
Another corresponding system is apparent in the west coast of Asia, though less regular, as its outline is varied by differences in the extent of the plains and slopes of the land. But we cannot fail to observe the curving lines from Okhotsk south to Pekin; from Pekin to Tongquin; and perhaps also from Tongquin to Malacca. The mountain ranges of the eastern side of the continent also correspond, as laid down on the best charts. The Stanovoi and the Khingan mountains form three great curves of similar character, convex in the same direction; and the Altai range, farther in the interior, is parallel with the last.

When the particular islands in the curved lines south of Kamschatka, are laid down with minute accuracy, there is reason to believe that each of the curves pointed out, will be found to be not a simple curve line throughout, but a compound one, having some degree of resemblance either to figure 2, 3, 4, 5 or 6.

On a large recent map of the Pacific and East Indies, the range of the New Hebrides (K, fig. 8) and the nearly parallel New Caledonia, (M,) is observed to be continued in the Salomon islands, New Ireland and Louisiade group, (I, G, H,) as before stated; but the range, we remark farther, is becoming to the westward, gradually more east and west in direction, changing from N. 40° W. to N. 65° W. The range does not stop here: it is continued

Fig. 8.





A. Sumatra; B. Java; C. Sumbawa; D. Ceram; E. North New Guinea; F. South New Guinea; G. Admiralty and New Ireland; H. Louisiade; I. Salomon Group; J. Santa Cruz Group; K. New Hebrides; L. Brittania Group; M. New Caledonia; N. Northeast Australia; O. North New Zealand.

in New Guinea, (E, F,) falling off still more towards an east and west course; and the southern division of it, at least, is continued farther through Flores, Sumbawa, and Java, (C, B,) and from the last island trends northward through Sumatra (A) and the Andaman Islands. This is an example of a long curving range; and we may properly connect with it, northern New Zealand, northeastern New Holland, and the islands between this coast and New Caledonia. Viewing the broad band, we observe the whole conforming to one system; and the separate parts, if analyzed on a good map, confirm each the same principles.

Malte Brun mentions the great range of the central Pacific from the Marshal Islands by the Samoan to the Austral Islands south of Tahiti, which is full 5000 miles long. Leaving the particulars for another place, we observe only that this great range curves north as it goes westward, varying from N. 66° W. to N. 35° W.

It is also true of mountain ranges that they have this compound character, though they have seldom been surveyed with sufficient care to allow of deriving much accurate knowledge of them from maps or descriptions.

In the valuable work on New South Wales, by Strzelecki, this intelligent and laborious traveller mentions and figures the successive curves, convex westward, which characterize the mountains of Eastern Australia, and without reference to any hypothesis, or to such a system of things elsewhere. Profs. Rogers in their elaborate papers on the Appalachians, mention that these mountains, in their course from Maine to Georgia, are made up of a series of great curves, which they describe separately and with detail. We shall allude, on a following page, to Dr. Percival's interesting observations on the trap ridges of New England, which sustain the same principles in all their detail. Sufficient has been brought forward to illustrate the general fact, that the great chains of mountains, as well as of islands, are interrupted ranges, consisting of overlapping lines, either straight or curved; and that curves constitute an essential feature in the system. We have, therefore, but a small part of the truth in the conclusion before stated, that there are two prevalent trends in the system of the earth.

There is still another point to be observed before we are prepared to draw any conclusions from the facts. Namely:—

VI. *The approximately rectangular intersections of two systems of trends wherever they occur together.*

The curving direction of the Java range has been pointed out in its course from Sumatra east. Looking again at the map, the reader will observe that the coast lines of the large islands north, are approximately north and south in direction; but vary exactly with the Java curve. Celebes and Gilolo are north and south (*ef*, *gh*, fig. 8) like western Mindanao; and correspondingly, the Java line in the meridian of Celebes, is east and west. The east coast of Borneo varies a little to the east of north, and a line drawn along it (*cd*, fig. 8) would meet the Java range at right angles, or where this range inclines about as many degrees to the north of west. The west side of Borneo varies forty degrees to the east of north, (*ab*, fig. 8,) and at the same time the Java range, where the line of this side continued would meet it, has a like variation to the north of west, not differing even a degree, thus making the intersection rectangular. Hence it would seem that the shape of Borneo was connected in origin with the trend of the Java range; and not only this, the whole surface covered by the islands from Luzon to the Java range, has nearly the same shape as Borneo.

The successive curves on the east coast of Asia, are nearly at right angles with one another at their extremities. Thus Niphon stands nearly at right angles with the south extremity of the Kurile range; so Kiusiu, with the same extremity of the Japan range: and also Formosa with that of the Loochoo range.

In New Zealand, the two systems, as shown by the outline of the group, are nearly at right angles. The Tonga range is nearly at right angles with the Samoa or Navigators. Passing by other facts in the central Pacific, the Galapagos present the same rectangularity of the two systems. The line of active vents in Mexico and that of the great chain are at right angles, as stated by Humboldt, and the former is parallel with Cuba. The Canaries present the same facts as the Galapagos.

We often find parts of a chain at right angles with the rest, as illustrated in figure 6. In the chain of lakes from Lake Erie to Bear, which has the *northeast* course, several of the lakes themselves are oblong *across* this course. This is the case with the parts of Bear lake, with Slave lake, Athabasca, and the northwest shore of Superior; and the whole line is at right angles with the line of the St. Lawrence, Ontario, and Erie. Indeed such facts are closely connected with those first stated with regard to the relation of the two prevalent trends of the globe, the northeast and northwest, and have long been recognised.

We have not alluded to a highly important branch of the subject:—the direction of cleavage joints in rocks. It has often been observed that there is a general correspondence between them and the direction of the mountain ranges of a region. Necker has presented a great variety of facts on this subject, showing the prevalence of northeast and northwest lines in Europe and elsewhere.* Professor Sedgwick, in 1831, stated the law of parallelism.† De la Beche mentions the same in Devon and some other parts of England, where north-northwest and a transverse direction are the common courses.‡ Phillips observes that in Yorkshire, fifty-five out of eighty-nine of the cleavage joints observed by him, were between northwest and north, and twenty-eight were at right angles with these; only six were anomalous. The same facts have been remarked by other English geologists. Fitton has presented similar facts from Australia.§ Mr. Darwin in his work on South America, gives various facts showing that the principle holds west of the Andes, that the cleavage joints are in general parallel to the mountain range. It is also true of the United States, east of the Appalachians. We observe therefore that the question with regard to the cause of this structure is intimately connected with that of the origin of mountains.

This survey of the geological features of our globe leads to several important conclusions.

A. *That the earth has a strongly marked physiognomy, or a system in its grand outlines.*

B. *That throughout this system, northwest and northeast lines are every where prevalent.*

C. *That these strongly drawn lines are usually curved instead of conforming to the direction of a great circle; and*

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* Bibliothéque Univ., de Genève, xliii, 166. 1830.
† Trans. Geol. Soc., London, ii ser., iii, 68.
‡ Geol. Rep. on Cornwall, Devon, and W. Somerset, 8vo, London, 1839.
§ Sketch of the Geology of Australia, Phil. Mag., lxviii, 135.

whether curved or straight, consist of a series of subordinate parts ; these parts having often a different direction from the line of the range.

D. *That the lines, even when curving, cross or meet any transverse lines very nearly or quite at a right angle, the one dependent on the other or varying with it.* Consequently—

E. *That the same grand chain may vary even sixty degrees or more in its course, and hence the trend of a ridge is no independent evidence of its age.* Thus a northwest course may gradually change to an east and west, as in the great Java range from New Hebrides to Java, and thence become northwest again, as in Sumatra:—a west-northwest range may change to north-northwest, as in the great Pacific chain from the Society Islands to the northernmost of the Marshall group. A north-northeast range may change through northeast, to east and west ; and also a north and south range may go through the same changes, as shown along the east coast of Asia and elsewhere.* Just west of New Guinea the east and west line is a little north of east in Timor. Consequently, while northeast and northwest lines are on the whole most common, there are other courses to be considered, and all are so dependent that they evidently must have a common explanation.

Causes of the Earth's Features.

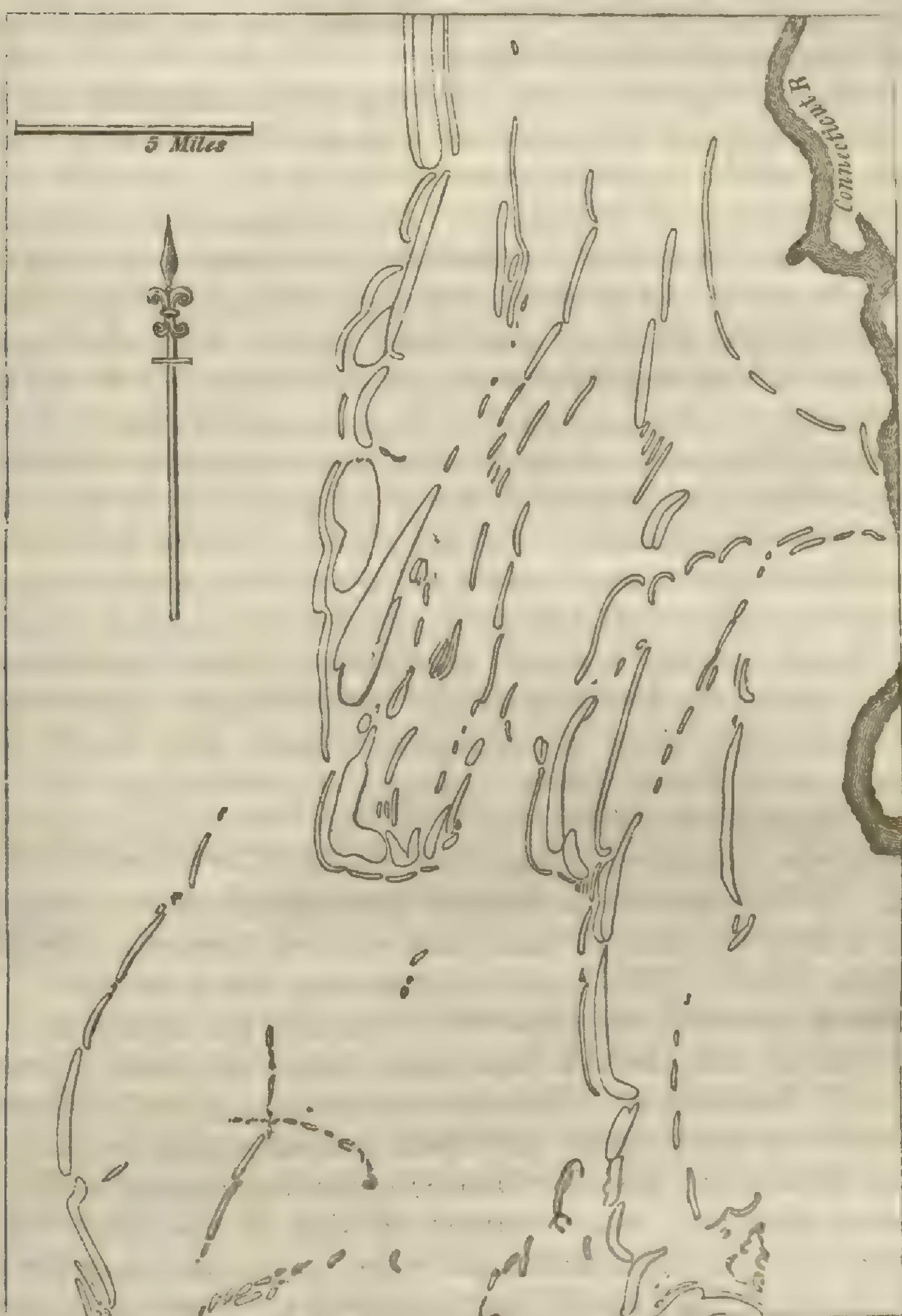
The direction of mountain chains is universally attributed to the courses of former fissures in the earth's surface ; and as islands come under the same head, and coast lines are mostly dependent on the ranges of heights adjoining, the question before us is reduced to this:—What can have occasioned such *ranges of fissures*, with their several peculiarities ; their composite character, general uniformity of direction, curves, irregularities, and usual rectangular intersections?

Peculiarities of Fissures.—Before proceeding farther, it is important to understand the general character of fissures ; and we present a case to the point from the map accompanying the elaborate Report of Dr. J. G. Percival on the Geology of Connecticut ;†—a work of vast labor, and of minute and cautious research, by one of the ablest men of America. Dr. Percival has afforded us a key to this subject, of the highest value, by the results of his investigations among the trap dikes of New England. The chart annexed is a small section of the map near its centre, showing the positions of the dikes or trap ridges. They commence twelve miles south of the portion here given, in the vicinity of New Haven bay, and extend northward into Massachusetts, and beyond into New Hampshire.

* The same principle is recognized by the Professors Rogers, in view of the facts observed by them in the Appalachians. Trans. Assoc. Amer. Geol., 1840–42, p. 540.

† Report, &c., by James G. Percival, 495 pp. 8vo., New Haven, 1842.

Fig. 9.



The dikes (courses of fissures) have the following characteristics:—

1. A general uniformity of direction.
2. A situation in several parallel ranges.
3. An interrupted character, and a frequent advancing or receding in the successive parts of a line, or an overlapping of the extremities, as in figures 1, 2, 4, 5, constituting what Dr. Percival has well designated "advancing," "receding" or "continued" series.
4. Curved lines; some simple, others composed of several straight lines, and others of subordinate curves.
5. Various irregularities in the lines, and deviations from parallelisms, although belonging to the same general system.

These peculiarities, as laid down and described by Dr. Percival, are confirmed by the writer's observations on dikes elsewhere and by fissures in volcanic regions.

We have in the above, an example on a comparatively small scale, of the general characters of fissures; and we find that it is an almost exact representation of the facts presented by the prominent features of the earth. The coincidences confirm the view that the ranges of mountains and islands correspond to ranges of fissures, and also illustrate their subordinate peculiarities.

The formation of many associated fissures, instead of a single rent, is the natural result from the general character of the material ruptured, and the manner in which the force must act.

Causes of the general uniformity, and composite character of ranges.—The most important point with relation to the ranges, is their general uniformity over the globe. These great systems of parallelisms must have arisen from the ruptures taking place in certain directions rather than in others, and the cause lies either in the forces causing ruptures solely, or in them in connection with the nature or structure of the earth's crust: and if the latter, the structure must be coextensive with the world, as the facts have no narrower limits. The annexed figure illustrates as we have stated a common character of ranges. To produce such a result must there not be two distinct causes, a force to rupture, and a structure to determine the direction of the lines? Were there no structure, the force should have produced a fissure in the general direction of the dotted line A B. But instead of this effect it produced a series of parallel lines oblique with this course. We can conceive of such a systematic result only on the ground that there is a tendency to fracture in a certain direction; and the force is applied obliquely to the lines of easiest fracture. Such ranges, as that of the Hawaiian for example, may exceed a thousand miles in length: and the great central range of the Pacific, 5000 miles long, illustrates the same point, proving the existence of directions of easiest fracture in the very nature of the earth's crust. The fact of such a structure has been suggested by Necker,* De la Beche,† Boué‡ and other geologists.

Fig. 10.

The nature of this structure, or the cause of this tendency to break in two directions, is a difficult subject of inquiry. The material of the crust, to which we naturally look for an explanation, is crystallized rock, for all igneous rocks are crystalline in their nature on cooling; and we observe that such rocks often break most easily, in certain directions dependent on the crystallization of some one of the included minerals or the position

* Bib. Univ. de Genève, xliii, 1833, 180.
† Geol. Report on Cornwall, Devon and W. Somerset. p. 281.
‡ Bull. Soc. Geol. de France, xiv, p. 439, 1843, and ii Ser., i, pp. 353, 355. 1844.

of crystalline grains; though there may be also other independent lines of fracture. There is abundant evidence of a uniformity of cleavage direction in the rocks of the surface over large areas, as already explained. Such a cause would have acted more uniformly at the first cooling of the surface, when from the previous free liquidity, the material was more uniform in character than at any time afterward: and even though the material were different in different parts, it matters little, since feldspar is common in almost every igneous rock, and is a frequent source of cleavage in two directions at right angles with one another, independently of the foliation due to mica and hornblend when either of these minerals are present.

M. Necker, in the article already alluded to, suggests that the trends of mountains, coast lines, and the strike of strata, coincide with *magnetic curves.* The same cause is appealed to by Boase* and De la Beche, on the ground that the electrical currents traversing the globe may influence the polar forces of crystallization. It has since been demonstrated by Mr. R. Hunt that the direction of crystallization is influenced by magnetism,† and R. W. Fox had before shown the action of electrical forces in determining the direction of lamination.‡ The magnetic chart of the world, by Captain Sabine in the sixth Report of the British Association, exhibits some striking coincidences throughout the Pacific; the exact trend of both the Hawaiian and Samoan groups and also the east and west courses in the East Indies and in the West Indies, correspond with lines on his chart. The exceptions are many and look insurmountable; but they are to some extent removed by a knowledge of other sources of influence. It should also be remembered that lines of magnetic intensity, as Brewster has shown, correspond nearly with isothermal lines; and the two agencies, heat and magnetism, must therefore have acted in some degree together, at all periods.§

Hopkins in his able "Researches on Physical Geology,"‖ (1835,) attributes the regularity of joints in rocks to the mechanical action of an elevating force, and he establishes a perfect uni-

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* Treatise on Primary Geology, by H. S. Boase, M. D.; 8vo, London, 1834, and L. and E. Phil. Mag., and Jour. of Sci., ix, 4; x, 14.

† Phil. Mag., Jan., 1846, p. 1: Amer. Jour. Sci., ii Ser., ii, 116.

‡ Report of the Polytechnic Society of Cornwall, for 1837, pp. 20, 21 and 68, 69.

§ M. Boue observes:—Sans avoir besoin de supposer que la terre ait été primitivement un cristal, it suffit de lui *accorder un certain ordre dans ses irrégularités de surface en harmonie avec son mode de refroidissement, ses forces intérieures et les forces centrifuge et centripète.* Ceci admis, on en doit déduire necessairement que les premières mers ont occupé les parties du sphéroide les plus accidentées, certaines grandes chaines offrant encore les indices de ces formes régulières, ou pseudo-régulières; et puisque ces séries de montagnes constituent l'ossature des continents, et déterminent leur figure, on voit de nouveau combien la similitude des continents eclaire *l'etude pour ainsi dire cristallographique du noyau terrestre.* Bull. de la Soc. Geol. de France, i, ii Ser., 355.

‖ Trans. Camb. Phil. Soc., vii, 1.

formity between the facts and the necessary effects of this cause. Mr. Darwin adopting essentially the same view in his remarks on the parallel relation of the planes of cleavage in western South America to the axis of the Andes range, explains the uniformity by supposing the mass to have been subjected to tension unequal in different planes, arising from the elevation of the mountains.* Mr. Sedgwick in his valuable memoir "On the Structure of Large Mineral Masses," (1835,) also appeals to tension as the cause, and supposes that this tension may arise from the contraction attending solidification.† If tension be the proximate cause, the various facts require that both sources of it, the mechanical and that of refrigeration, be equally appealed to.‡ With reference to this subject, it should be considered that if curves of magnetic intensity are approximately isothermal lines, they must have been lines of equal cooling, and consequently *lines of equal tension.* This cause would then coöperate with the electrical, and might aid in producing the general uniformity of trend, which could not proceed from contraction alone. Acting during the period of early cooling, its effects should therefore have been universal: and through subsequent ages, the cooling or crystallization, *beneath* the crust, making still slower progress, (inconceivably slow,) would have continued to be governed by the same cause, liable to those modifications that isodynamic lines have undergone. But a perfect correspondence in the *surface* plutonic rocks, with the structure of the crust, should not be expected, since the lines of tension, determining the structure of the former, must have depended somewhat on the direction of the force producing fissures and mountain elevations.

The bare possibility that the earth's axis of rotation has been at any time changed, suggests that a cause may have coöperated in these results, whose influence cannot be fully estimated. Yet if magnetism has been a cause of structure, the coincidence of trend with existing curves of magnetic intensity tends to prove that such a change of axis has not taken place. It would be a grand result for geology if the science should settle this debated point. The coincidence of the magnetic curves with the trends in the central Pacific and north of New Holland, and also in the West Indies, is so close, that we have reason to suspect that the two facts are some way mutually dependent and have always been so. Still if the earth's axis may have changed, it is possible that the trends may once have had a direction that could have been

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* Darwin on South America. 8vo, London, 1846. p. 163.

† Trans. Geol. Soc., London, ii Ser., iii, 480, March, 1835.

‡ Tidal movements in the fluids during incipient cooling might be a source of tension, transverse to the line of motion. And a gradual change in the oblateness of the globe would be another source of tension. But it does not appear that the existing system would correspond with the possible effects of either of these causes.

mainly caused by tension consequent on a diminution of the earth's oblateness.

Whatever the origin, there can be no doubt of the *fact*, that a kind of cleavage structure, or, at least, a capability of fracturing most easily in two directions, was given the crust during its formation, and that such a structure has influenced the direction of the lines of fissures that have since taken place. And while there is evidence of this structure, there is proof that the rupturing force often acted obliquely to the planes of easiest fracture, causing deviations from straight lines in the long ranges. The next question is with reference to this *rupturing force*.

Contraction is a known dynamical cause that must have begun with the beginning of refrigeration; and it is hence essential to consider how far it meets the various facts in view. In the theory of mountain ranges, by Elie de Beaumont, this agency is appealed to; we believe as confidently in its efficiency, though led by the facts to somewhat different results.

The effects of contraction have been illustrated elsewhere in this volume. A prime feature in the operation of cooling, influencing all the results proceeding from it, depends on the tendency of heat to spread itself circularly, or to diminish circularly, around a centre. This cause gives a circular form to pools of lava, and they retain this form as they cool. The great crater areas of the moon, several hundred miles in diameter, illustrate it; and this size is no necessary limit to their extent. In a cooling globe there would therefore be necessarily such vast circular or elliptical areas. Here then we perceive a cause modifying all the results of cooling; and we observe that throughout all ages there must therefore have been some reference to such circular or elliptical areas in contraction; and especially, to aggregations of such areas, which also would be more or less curvilinear in outline, and would act as a whole in the progressive subsidence.

The force of tension in the crust from contraction beneath, is exerted to a great extent horizontally; and in a subsiding area, the direction would be nearly radial, or from the centre outward. This cause then should generally *act obliquely to the lines of structure*, though sometimes coincident with them. If the tension cause ruptures, the rents should follow the lines of cleavage structure in the earth, in case the direction of the force corresponded; otherwise a series of rents should result having a direction of range different from the direction of the line of structure. The peculiarities of fissures, which have been explained, the "receding," or "advancing," or "continued" series of parallel courses, and the curved directions, are therefore necessary effects of the cause appealed to. Curved as well as straight ranges, ought therefore to characterize the grand features of the globe.

The important generalizations of Mr. Hopkins with regard to the *direction of fractures* and the necessary *dependence of two* *transverse lines* in an elliptical area under a state of tension, not only remove any difficulty arising from the existence of two transverse systems and their rectangular intersections, but actually require this result.*

Areas of non-contraction or of comparative slow contraction, should modify the direction of the ranges of fissures formed in a surrounding region where more rapid contraction is going on. Also, the interference of two contracting areas would produce irregularities; still wider effects would proceed from more extended combinations, such as have produced the oceanic depressions and the continental areas. Thus the continents which were early free from fires† have generally experienced the tension along their borders; and fissures and mountain ranges, frequently several in parallel series, have been formed, whose main courses are a resultant between the direction of the planes of cleavage structure in the earth and the action of the force of tension arising from the contraction going on over the oceanic areas.‡ Causes of certain irregularities in mountain ranges were mentioned on page 185 of the last number of this Journal, and these discussions afford a more extended view of the action of these causes. The principles explained in the paper just referred to, have here their full application.

Any other cause besides contraction, occasioning elevations or subsidences would produce the same general result as regards direction of lines of fissures; but we know no other cause of probable operation that would be so related to elliptical or circular areas; and thus none but this cause appears to satisfy the conditions presented in the frequent curvilinear forms of ranges.

The positions of some great contracting areas may be distinguished over the oceans, from the curving lines which enclose them. The great Pacific range of lands, from the Marshall Islands to the Society group, 5000 miles in length, has been described as convex to the southwest, while the line of the Hawaiian range, 2000 miles long, is nearly straight. May not this part of the ocean have been one of the large *compound* contracting areas, and a line from Pitcairn's, in lat. 25° S., long. 130° W., to northern Japan the course of its axis? Using the registers of

* The mathematical deductions of Mr. Hopkins were made with special reference to the elevation of the Wealden, though brought out so as to be of general application. He lays down the facts, that in "districts where faults abound, two distinct systems are usually found, in each of which the faults approximate to parallelism with each other;" and that "the common direction of one of these systems is approximately perpendicular to that of the other;" and he establishes the necessary dependence of these transverse systems by calculation.

The mode of producing the tension required by fracture is different in the foregoing explanations, from what is assumed by Mr. Hopkins; but it does not appear to alter the general results; and it is believed to set aside some objections urged by Dr. Boase to the conclusions of Mr. Hopkins. See *L. and E. Phil. Mag., and J. of Sc.*, ix, 4, 171, 368, and x, 14. 1836.

† See this Journal, ii, 132, and iii, 181.

‡ Ibid, iii, 98, 181.

subsidence, so happily distinguished and brought forward by Mr. Darwin, the Coral Islands, we have evidence that an elliptical area with the same line for its axis was subsiding even as late as since the tertiary epoch. The very region therefore which bears evidence of having been the original great elliptical area of contraction for the Pacific, on which the courses of the islands were in part dependent for their direction, was also undergoing contraction till within a late period; and we know not that some parts about the Northern Carolines—the nearest to the centre of the area—may not still be contracting as there is some evidence of it, which the writer will elsewhere present. The *transverse* line including New Zealand, the Kermadec and Tonga Islands, crossing the other systems nearly at right angles, would pass in its course northward the Samoan and Hawaiian Islands, and also some smaller groups intermediate.

The position of a large area undergoing *little contraction compared with the region around*, is before us in New Holland, as is evident from the absence from this semi-continent of volcanoes or their remains. Such an area would occasion a tension acting to some extent circularly around it; and which might determine the courses of ranges in its vicinity. The ranges of islands from New Zealand by the New Hebrides to New Guinea and Java, is just such a concentric range, as the view would seem to require. Borneo is another vast region without volcanic traces over its interior, and may have influenced the upward trend exemplified in Sumatra. However this may be, the cause brought forward—large isolated areas of comparatively slight contraction,—must have had their influence in determining the direction of lines of tension or of forces causing rupture.

M. Boué remarks that the trends in the tropics in general approach a parallelism with the equator, and he attributes the supposed fact to the centrifugal force of rotation. It holds true to a considerable extent. There are however so many exceptions that we may perhaps doubt whether the fact is sufficiently general for so general a cause.

The conclusions which appear to flow from the facts that have been presented, are as follows:—

That the general direction and uniformity of the grand outline features of the globe may be in a great degree the simple effects of the earth's cooling: this operation resulting in (1) solidification, and under the circumstances, whatever they were, an attendant jointed structure or courses of easiest fracture, in two directions at right angles nearly with one another, both varying together according to the rates of cooling in different parts;—and (2) occasioning tension in the crust through the contraction going on beneath, with some relation to circular areas but especially to large compound areas, which tension caused ruptures conforming or not to the lines of jointed structure according as the force of tension acted in accordance with this structure or obliquely to it. (3) The age of mountains cannot therefore be determined necessarily by their courses; a different direction in a particular region in different ages is not improbable, since the same contracting area might exert its horizontal force in somewhat different directions at different epochs, or other such areas might coöperate, and exert a modifying influence; and at the same time, an identity of direction for different ages was to have been expected.

From the facts before us it may be inferred that the great volcanic band which is drawn by von Buch in the East Indies, in the shape of the letter U, from Sumatra and Java around by the Philippines, gives an incorrect view of the volcanic system in that part of the world. Much the larger part of the Philippines consists of primary and secondary rocks instead of volcanic, and in Luzon, the southern volcanic portion corresponds nearly to the west-northwest trends of the Pacific. The volcanic line of Sumatra and Java, including also the islands farther east, belongs, as we have shown, to the system of the Pacific, to the northwestward courses which characterize nearly all the groups of that ocean; and it is continued east by a volcanic line along North New Guinea to the New Hebrides. Although an erroneous impression may therefore be conveyed by the chart of von Buch, it presents properly the fact intended to be illustrated by its distinguished author, that volcanoes prevail along the track laid down. The band seems like a grand volcanic border to the Asiatic continent, stretching from the vicinity of northern New Holland, (and we may say from New Zealand,) to Kamschatka; and it curves around into the great American range through the Alaschka Archipelago.

It is a fact of no little interest that the Pacific Ocean should thus be nearly encircled with volcanoes, active or extinct, as well as by high mountains, while the sides of the narrow Atlantic and Indian Oceans have comparatively few traces of such fires; and it tends to confirm the opinion thrown out as to the agency by which the deep ruptures and elevated ranges of the globe have been produced.*

This subject properly forms an introduction to the preceding papers on the earth's contraction, in this volume;† and the whole is offered as a simple view of the earth's dynamics, the sufficiency of which is to be tested by future discoveries.

Note.—On page 188, it is implied that Lyell and Poisson admitted the former fluidity of our globe; whereas the writer simply intended to acknowledge that these authors first brought forward the argument that a crust could not form upon a globe while it was in a state of free liquidity. See Lyell's Principles, ii, 439, where Cordier is mentioned as having presented the argument subsequently to himself.

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* See this volume, pp. 96, 98, 181, 185, 186. † Ibid, pp. 94, 176.