IV.—THE DISTRIBUTION OF '*TEREBELLA*' *CANCELLATA*.

By Dr. F. A. BATHER, F.R.S.

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'*TEREBELLA*' *cancellata* was the name given to some supposed worm-tubes from the Cenomanian of the East and South-east of England, in the GEOLOGICAL MAGAZINE for December, 1911 (p. 553, pl. xxiv, figs. 3–5). The chief feature of the species is an obscure cancellate ornament formed by transverse and longitudinal folds.

At that time these fossils were recorded from the *Holaster subglobosus* and *Actinocamax plenus* zones of the Cenomanian. The only exception was the British Museum specimen A 1638 from the Upper Greensand (Albian) of Betchworth, Surrey. Some other horizons can now be added.

Aptian: Specimen A 1702, collected from the Lower Greensand of East Shalford, Surrey, by Caleb Evans.

Turonian: a specimen submitted in June, 1917, by Mr. H. C. Brentnall, of Marlborough College, and obtained "just N. of the main road over Overton Hill and S. of the short stretch of Roman Road, just W. of the 4th milestone. On the 6 in. map, Wiltshire, Sheet XXVIII S.W., the actual shallow excavation is shown under the word Tumuli". This is probably the "small pit" in the Chalk Rock, zone of *Holaster planus*, mentioned on p. 197, par. 5, of Mem. Geol. Surv., Cretaceous Rocks of Britain, Vol. III.

Lower Eocene, THANETIAN: Specimens A 1936 – A 1940, collected by Captain P. R. Lowe, R.A.M.C., in July, 1917, from the quarries near Wizerne, on the south side of the River Aa, near St. Omer. The matrix is a soft, friable, glauconitic sandstone, of a pale yellow colour. Among the associated fossils are internal casts of *Thracia* and of a *Pholadomya*, probably *P. konincki* (*fide* R. B. Newton). The map of the French Geological Survey applies the name Sables de Bracheux to this outcrop, but the fauna is not that of the type-locality. In some of the specimens the cancellate ornament is well defined, and in A 1939 the lines run diagonally (compare op. cit. p. 551, line 4 from end, and fig. 4).

The first point brought out in this note is the extended range in time of *Terebella cancellata* from Aptian to Thanetian.

The second point is the constant association of this form with a glauconitic facies and a fauna relatively rich in mollusca.

V.—ICELAND—A STEPPING-STONE.

By E. B. BAILEY, M.C., B.A., F.G.S.

1. INTRODUCTION.

WHEN in 1897 Sir Archibald Geikie published his important monograph on the *Ancient Volcanoes of Great Britain* he devoted chapter xl to a description of Iceland—so largely does our North Atlantic neighbour bulk in the eyes of British vulcanologists.

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Geikie drew the greater part of his informatiom from Thoroddsen's writings, supplemented by those of Helland, Tempest Anderson, and Johnston-Lavis. His theme throughout was the conspicuous and abundant evidence afforded of fissure eruptions.

Since then various other publications have appeared dealing in English with the volcanic phenomena of Iceland. Of these we may mention three in particular:—

In 1901 Thoroddsen brought out his *Geological Map of Iceland* on the scale of 1 : 600,000. It is a truly magnificent achievement, representing much of its author's life-work in the field from 1881 onwards to 1898.

In 1909 Suess supplied further summaries of Thoroddsen's results, especially in regard to ring-fractures, cauldron-subsidences, and earthquakes. His descriptions, accompanied by two of Thoroddsen's small-scale maps, will be found on turning to vol. iv, p. 262, of the Sollas (English) edition of *The Face of the Earth.*

In the same year Clough, Maufe, and the present writer contributed a resumé of Spethmann's 1908 paper[1] on Askja, Iceland's greatest volcano. This short account is illustrated by Spethmann's own map, and starts on p. 666, vol. lxv (1909) of the Quarterly Journal of the Geological Society. Its intention is to facilitate comparison between the cauldron-subsidences of Askja, in Iceland, and of Glen Coe, in Scotland—Askja, of post-Glacial age, with its deep caldera and its rim-craters and solfataras; Glen Coe, of Lower Old Red Sandstone age, with its caldera form obliterated by erosion and its external ring of intrusions bared by the same agency.

Since Glen Coe was described much has been written by members of the Scottish Geological Survey on ring-fractures and ring-intrusions; notably by Maufe in relation to Ben Nevis, and by Wright, Richey, Clough, and myself in regard to Mull. As time goes by the value of a knowledge of Thoroddsen's observations in Iceland becomes more than ever apparent. Accordingly some years ago I prepared an abstract of "Die Bruchlinien Islands und ihre Beziehungen zu den Vulkanen",[2] a paper already referred to by Suess. This abstract, rearranged, forms Part 2 of the present communication. Part 3 is a definitely speculative venture, in which Suess is in large measure adopted as guide, though in certain important matters his conclusions are set aside.

The map of Iceland, p. 468, is based essentially on Thoroddsen's 1905 map, somewhat reduced in scale, and with the earthquake districts and much of the topography omitted. The outcrop of the Older Tertiary Lavas is an additional feature derived from Thoroddsen's 1901 map. It should also be pointed out that Thoroddsen merely shows the Askja Caldera as a geographical feature, whereas in accordance with Spethmann's observations I have ventured to surround it by a ring-fault, with a minor subsidence indicated inside.

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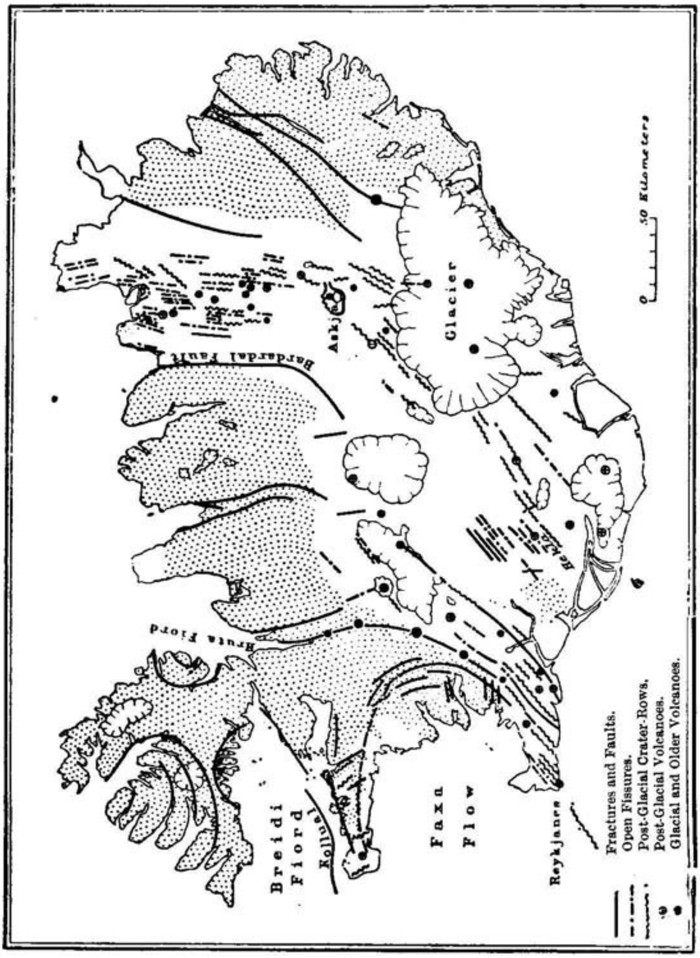
[1] "Vulkanologische Forschungen im östlichen Zentralisland": Neues Jahrb., xxvi, Beilage-Band, p. 381, 1908.

[2] Peterm. Mitth., Band li, pp. 49–53, with map and crater-plans.

2. THORODDSEN ON ICELANDIC FRACTURES AND VOLCANOES.

Geologically, Iceland is divisible into two, an Old and a New. The Old is not continuous, but is separated by the New into an eastern and a western province. In Old Iceland basaltic lavas of early Tertiary date, comparable with those of Antrim and the Hebrides, are everywhere exposed to view. In New Iceland these ancient lavas are concealed by widespread volcanic accumulations reaching down, in point of time, to our own day. The difference finds expression in many other ways than in the nature and age of the prevailing surface rock. As a volcanic district New Iceland is active, whereas Old Iceland is extinct.



Iceland, after Th. Thoroddsen. The Early Tertiary Basalts are stippled. The more recent volcanic rocks, from the Pliocene Breccia Formation onwards, are left plain.

The differentiation of the New Iceland from the Old seems to have been effected at the close of the Miocene Period, when the basaltic plateau developed fractures and began to sink. In Pliocene times numberless outbursts gave rise to a great bow of palagonite tuff and breccia, which, with its later associated lavas, is the country rock of New Iceland from coast to coast. Since then volcanic activity has been more or less continuous, always within the same restricted area: in late Pliocene times and probably also during the Glacial Period, extensive lava fields of dolerite were produced, followed throughout post-Glacial time, by widespread outpourings of basalt with very subordinate liparite; the post-Glacial basalts, considered by themselves, cover an area of little less than 11,200 sq. km.

Erosion has stripped Old Iceland of much of the spectacular accoutrements of vulcanicity. What meets the eye for the most part; is an immense pile of basalt flows dipping very gently inwards from either side towards the arcuate belt of tuff, breccia, and later lavas. Often, indeed, the early lavas are practically horizontal, more especially in the much-faulted coastal region lying between the Bardardal and Hruta Fiord Faults.

In some ways the most interesting feature of Old Iceland is the ring-fracture system (*Kreisbrüche*) of the north-west peninsula. There, lignites, clays, and leaf-beds, interbedded with the lavas, serve as valuable indices to the displacements the country has undergone. The lines of ring-fracture are sometimes marked by warm springs and parallel open cracks. And according to Suess, who evidently relies on the paper in which Thoroddsen elaborates his discovery, each ring-fault steps both the geology and the topography down towards the centre, while the intervening annular strips slope gently outwards towards the periphery.

In harmony with the ring-faults of the north-west peninsula are the cauldron-subsidences of Breidi Fiord and Faxa Flow.

The Snaefellsness Peninsula, separating these two great bays, is a horst, and consists mostly of old basalt, in part covered by the Breccia Formation and later basaltic lavas. It is cut by cross-faults locally depressing the old basalt platform below sea-level.

The sunken area of Breidi Fiord on the north, includes on its bottom a grabe called Kollual, 75 km. long and 9 km. broad. That of Faxa Flow, on the south, is bounded by faults, with a downthrow of 200–300 m., lined with hot springs and crater-rows. Faxa Flow is very liable to earthquakes, and altogether, both in its rocks and in its behaviour is perhaps in as close alliance with the New Iceland as it is with the Old. In Old Iceland, close fractures, faults, and lines of hot alkali springs occur, but not solfataras; while, except about Faxa Flow, earthquakes and glacial and recent volcanoes, including crater-rows, are rare. In New Iceland, gaping fissures, graben, and solfataras (with subordinate alkali springs) are all common; so too are earthquakes, crater-rows, and big volcanoes.

There are five earthquake districts in Iceland. All border the coast, and all, save Faxa Flow, belong to New Iceland.

About as extensive as the Faxa Flow district, but reaching in the other direction, east from the base of the Reykjanes Peninsula, is a particularly complex field of subsidence and unrest. The district is broken into segments which behave independently during earthquakes, the while the great neighbouring volcanoes stand passively indifferent. Far away on the northern coast are three more earthquake districts. In the interior highlands earthquakes are rare unless in obvious connexion with volcanic activity.

The boundaries of New Iceland now deserve attention. The western margin, where not concealed by superficial accumulations, is seen to be largely determined by two arcuate faults, each with a downthrow towards the convex eastern side. The opposite margin is less definite, for here the early Tertiary lavas dip gently beneath the Breccia Formation. Of the two border-faults on the west of New Iceland the outer one is the older. It runs from the Reykjanes Peninsula northwards to the Hruta Fiord. Its course is marked by the ruins of great extinct volcanoes. The inner fault, known as the Bardardal Fault, first originated after great areas had been covered beneath post-Breccia dolerite lavas. The boundary of New Iceland where it runs east and west between the Hruta and Bardardal Faults is very obscure owing to its being hidden beneath glacial and similar surface deposits.

The topographical character of New Iceland is distinctive in the extreme. Every feature in the north runs from north to south, and in the south from north-east to south-west. This is all due to the course taken by volcanic fissures, too numerous for individual representation on a map. Many parts of the district, lowland and highland, are literally striped by them.

Often lava-flows cut by the fissures have undergone considerable subsidence. Near the head of the northern branch of the long inlet east of the Reykjanes Peninsula, an old subsidence 60–70 sq. km. in extent, and 30–50 m. in depth between two fissures known as Almannagja and Hrafnagja, sunk two or three additional metres during a violent earthquake in 1789. Of more recent date and more considerable magnitude are certain graben of the Odadahraun—the district neighbouring Askja—where, in one instance a fault-scarp 30–40 m. high continues for a distance of several kilometres.

In two instances fissures which have yielded lava, remain open and craterless; Eldgja, one of the two, in a single outburst yielded 9 c.km. of lava. But almost always a crater-row has been erected along the course of an active fissure. Such rows extend sometimes from 10 to 35 km. The craters vary greatly in form: they may be elongated, or they may have one ring within another, or one wall collapsed, the other standing. Their height is commonly from 10 to 200 m.

A fissure sometimes continues open for as much as 15 km. at a stretch. Looking down into it one generally notices water or snow. It is difficult to separate the non-volcanic from the volcanic, for many a fissure of non-volcanic aspect where first encountered is found to have poured out lava at some other part of its course. Small parallel fissures without volcanic activity often accompany the more important volcanic fissures.

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Generally a fissure is only used once, but the well-known Laki fissure, with its crater-row dating from 1783, carries upon itself a crater of prehistoric age.

Most of the volcanic fissures are not accompanied by faulting, though this is a rule to which there are numerous exceptions. Two more examples may be quoted.

One of a series of graben occurring 25 km. east of Myvatn—north of Askja—had for a time fault-scarps 10–20 m. high, 15 km. long, and 400–500 m. apart. During a great earthquake in 1875 lava rising along the western wall, filled this depression. Then a crater row 22 km. long was developed, and poured out 300 c.km. of lava. The Ögmundarhraun lava in the neighbourhood of Krisuvik—east of Reykjanes—is also interesting in this connexion. It issued in 1340 from two parallel fissures. The southern part of the strip between these fractures has sunk 66 m. since the beginning of the outflow, and on the western wall overlooking the subsidence are the halves of four bisected craters of which the corresponding halves have been carried downwards.

A major fault has not always located the volcanoes of its neighbourhood. These are often situated on parallel fractures, *especially on the upthrow side of the great dislocation.* I have ventured to italicize the foregoing statement, as it is so reminiscent of the distribution of the intrusion which rose along the fault boundary of the cauldron subsidence of Glen Coe. The Icelandic examples chosen by Thoroddsen to illustrate this tendency are as follows :—

For 50 km. a fracture reaches from Krisuvik (east of Reykjanes) to Hengill, where the northern side has sunk 200–300 m. Parallel with it on the upthrow side is a wonderfully continuous system of crater-rows borne on subsidiary fractures. A similar case occurs on the south side of the Snaefellsness Peninsula overlooking Faxa Flow. Here too the craters are mostly on the upthrow side.

At the same time Thoroddsen does not wish to emphasize this point. In the Odadahraun, craters mostly occur on the margins of horsts. In Myvatn, farther north, the marginal position recurs, though other crater-rows are found upon the mountain horsts. What is clear about the distribution of contemporary vulcanicity in Iceland, viewed as a whole rather than in detail, is that it characterizes a great field of subsidence—to which in the present summary the name New Iceland has been assigned.

Choked eruption-fissures and the ruins of major volcanoes persist from Tertiary and Glacial times, but crater-rows of any but post-Glacial age have been dismantled. The following statistics refer solely to post-Glacial occurrences of various types of volcanoes. Thoroddsen has counted 87 major eruption-fissures with their attendant strings of craters; 6 strato-volcanoes (Vesuvius type); 16 lava-domes (Kilauea type); 13 explosion craters and crater-groups (Puy type); 2 sub-Glacial outbursts. Of these 130 post-Glacial volcanoes 25–30 have been active during historic times.

The accumulation of material that goes to make up a great volcano, whether of the Vesuvius or Kilauea type, often renders the original dependence of the volcano upon a fissure a matter of hypothesis

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rather than of observation. This cannot be said, however, of the strato-volcano Hekla (1,557 m. high), which extends 27 km. parallel to the local fissures, and only 2–5 km. at right angles to them. Regarding the Kilauean domes, where the difficulty of interpretation is admittedly great, Thoroddsen summarizes his position as follows: "The geological evidence shows above all that the Icelandic domes have been built on fissures where the eruption canal has been opened so wide as to give unimpeded egress to the lavas." Askja, with its caldera 55 sq. km. in extent, he points out, is situated at the crossing of two major fissure-systems; and he indicates on his map that its caldera is margined to some extent by a crater-row (Spethmann on his large-scale map shows additional rim-craters and solfataras). He further mentions an explosion-crater as having arisen on an obvious open fissure near the edge of a considerable subsidence which in 1875 affected about a quarter of the bottom of the Askja Caldera.

The 1875 eruption at Askja, and another of earlier date, 1724, at Viti, are the only two known to have given rise to explosion craters during historic times. Both eruption centres produced nothing but ash; but the relief of pressure in each case seems to have upset the equilibrium of neighbouring districts, leading to great subsidence and fissuring, and to an immense outpouring of lava.

Viti enjoys the rare distinction of being to all appearance unconnected with any fissure that has reached the surface. It has built but a small cone, so that the surrounding country is open to observation.

3. SUESS ON LUNAR CRATERS AND TERRESTRIAL ARCS.

In the paper already referred to, read before the Geological Society of London, Clough, Maufe, and the present writer suggested an analogy "between the Glen Coe cauldron of Old Red Sandstone times, with its girdle of fault-intrusion, and the Pacific Ocean of to-day, with its fringe of marginal volcanoes". The source of inspiration is not far to seek. While we were mapping in Glen Coe we felt as though we were reading Suess again, and that our discoveries had already been in large measure described in vol. i of that author's masterpiece.

Naturally, on the appearance of vol. iv of the Sollas edition of *The Face of the Earth*,[1] we turned with keen anticipation to those passages in which Suess develops his earlier conceptions of cauldron-inbreaks and arcuate structures in general. We found there an introduction to Thoroddsen's work on the ring-fractures of Iceland, dealt with in Part 2 of this communication, and also much additional matter which serves as the basis of the discussion that follows.

After recalling how, at the conclusion of vol. i, he had already

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[1] The many page references that follow all refer to this volume. In its footnotes the original sources may often be traced. For additional information, including several very helpful illustrations, the reader may advantageously consult the corresponding parts of tome iii of the de Margerie edition, *La Face de la Terre*.

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stated that the oceanic basins of the earth originate and increase through subsidence and inbreak, Suess turns his attention to the "seas" and craters of the moon, and suggests that Iceland with its ring-fractures and cauldron-subsidences may furnish us with a true conception of the lunar surface (p. 598). He develops this comparison in some detail, and then passes on, as one might expect, to Southern Italy, and claims the Calabrian earthquakes as marking the growth of a *caldera* of lunar type under our very eyes, with the Lipari volcanoes at its centre and Etna on its periphery.

Suess also refers (p. 595) to a well-known tendency of major craters of the moon to carry minor craters "riding" upon their margin—as Etna may be said to ride upon the Calabrian cicatrice. He suggests that this riding on the ancient rampart may be accounted for as a result of peripheral fissuring. His terrestrial analogues he derives from Italy; but, had he known, he might have pointed once more to Iceland, to the rim-craters of the Askja Caldera; or he might have invoked the aid of Scotland, and interpreted the riding craters as the surface manifestation of ring-dykes of the kind now known to occur at Glen Coe, Etive, Ben Nevis, and Mull.[1]

It appears from what Suess says that he had no hesitation in classifying together cauldron-subsidences of the most diverse dimensions. On the one hand, he compares the cauldron-subsidences of Iceland with certain sinkings which have followed in mining districts upon the extraction of salt, or the draining of a substratum of quicksand (p. 264); on the other hand, he links them with lunar craters and with depressions of oceanic extent, whether lunar or terrestrial—although admittedly with increased extent the circular form tends to disappear (p. 598).

This grouping of large and small may be quite mistaken, but it is likely to be accorded a very general sympathy. The most diminutive of the phenomena chosen by Suess for comparison is a series of arcuate fissures found by him in an asphalt pavement which was sinking differentially as compared with its curbstone (p. 503). "The subsidences of the asphalt pavement take place," he says, "on the concave side of each of the several arcuate fragments. . . . A similar process seems to have occurred in the north-west of Iceland." One should not forget, however, that important exceptions are afforded along the western margin of New Iceland, where Thoroddsen finds the downthrow on the convex, and not the concave, side of the boundary faults.

Leaving Suess for a minute it may perhaps be profitable to draw attention to other instances of what appear to be ring-fractures on a small scale. About 3 per cent of the older cracked picture surfaces of a collection such as that of the National Gallery in

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[1] The investigation of these occurrences has been among the happy duties of the Scottish Geological Survey. Those mainly employed on the work have been H. B. Maufe, C. T. Clough, H. Kynaston, W. B. Wright, J. E. Richey, and myself. Many of our results are given in two Survey publications, *The Geology of Ben Nevis and Glen Coe* (1916) and *Summary of Progress for 1914* (1915).

London show very well-defined groups of circular fractures. They occur in concentric systems side by side with the more usual irregular cracks of the type known to geologists as suncracks—from their frequent development in drying clay. Circular fractures play a much greater rôle in the general crack system of less carefully guarded canvases. In fact, almost every out-of-door painted canvas, or linoleum, carrying a notice or advertisement, or stretched to cover a tradesman's cart, shows circular fractures at one place or other of its surface. Perhaps these fractures are analogous to the circular cracks of a broken pane of glass, and in any case great care should be taken in their interpretation. Indeed, they may not deserve the name of ring-fracture at all. A ring-fracture in geology follows a more or less cylindrical surface, and it should be remembered that quite other fractures, better styled cone-fractures, have an equally marked tendency to arcuate outcrop. Cone-fractures are now well known through Harker's work on the inclined sheet system of Skye and the later researches of others on the analogous systems of Mull. But returning from this digression, let us recall the most numerous ring-fractures of recent times. They originated in concentric systems within and about shell-craters, when the impalpable dust of the inner slopes contracted, and no doubt at its lower levels flowed, after its first wetting by a shower of rain.

The occurrence of arcuate volcanic fractures in Iceland, sometimes with a great radius of curvature and determining the site of major volcanoes, seems to lead naturally to a comparison with other volcanic arcs such as that of the Aleutian Isles. But Suess does not follow this line of approach. For him Icelandic arcs are a phenomenon of subsidence, whereas the mountain arcs, with which he classes the Aleutian Isles, are a phenomenon of lateral compression. I venture to think that if he had lived much longer he would have claimed a community of origin for the two systems of arcs. His ideas in this connexion seem to have been undergoing evolution as he wrote.

Early in his scientific career Suess started out to study the development of the Alps. He travelled far, and, though outstripped as time went on by certain of his comrades, he had good reason to be content. He could afford to let others struggle on towards the coveted summits of Alpine interpretation, while he lingered at a lower level; for he had learnt to use the writings of others as an astronomer uses a telescope, and through them to gaze upon the face of the earth from chosen vantage points, and thus to enrich two generations of geologists with a wisdom and knowledge gathered from every corner of the globe.

It is not surprising that at first he should regard the arcuate form of the Alps as a combined result of push and obstruction. Nor is it surprising that at first he should think of the Alps as typical of the other arcuate chains of the earth's surface, and extend his conception of push and obstruction to account for the configuration of the whole class.

If, like Darwin, he had learnt his geology on the borders of the Pacific Ocean he might well have had quite a different outlook in this particular. And as it is he seems to have turned increasingly to the

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Pacific ranges for information regarding the essential features of arcuate mountain chains. The account he gives of them can best be realized by reproducing certain of his statements.

"Three arcuate and concentric elements occur in the Asiatic island festoons, namely, the foredeeps, the folded chains (cordilleras), and the volcanic lines" (p. 504).

In the Bonin Islands of the Pacific, concentric zones are recognized as follows:—

1. Foredeep.
2. Tertiary belt, often folded.

3*a*. Folded cordilleras, the innermost sometimes backfolded.

3*b*. The volcanic arc "*always in the cordillera, and more precisely in the zone of forefolding*, never in that of backfolding, and never in the foredeep.

"The same structure is also present in the Northern Antilles, but in these islands no cordilleras occur within the volcanic zone. In general, the cordilleras are the first to show a tendency to disappear, as may be seen in the Bonin islands, while the volcanos hold their ground with great tenacity as in the Aleutian islands" (p. 516).

"As a result of these comparisons we see that the North Antilles (probably also the South Antilles), the Alaskides and all the island festoons as far as the Philippines, the Oceanides also, and in Asia the oppositely-curved Burman arc, present a similar structure, and this structure, although less sharply defined, is also perceptible in the southern marginal arcs situated in great part on the mainland.

"The constant occurrence of the arc of active volcanos within the zone of forefolding is a remarkable fact" (p. 524).

It is not only in his descriptions of mountain chains that Suess seems to contradict his old theory. We have already referred to his observations regarding certain arcuate fractures developed during the partial subsidence of an asphalt pavement under conditions wherein tangential pressure played no part whatsoever. As stated above, he compares these arcuate fractures with those of Iceland, but he is obviously more interested in their reproduction of the phenomena of *linking* and *syntaxis*, so characteristic of the mountain systems (p. 503); moreover, he returns to their consideration when he discusses the origin of foredeeps (p. 505).

And yet his views in regard to the cause of the arcuate form of the various elements of mountain ranges do not seem to have altered. The arcuate mountain fronts he compares with certain moraines described from Greenland, where inland ice, forcing its way between nunataks, sometimes carries ground moraine up from the bottom, and spreads it in arcs over ice in front, acting the part of foreland (p. 528); and the foredeeps, he says, "are subsidences of the foreland beneath the folded mountains" (p. 295).

The difficulty of this theory is that it gives scant recognition to the volcanic arc, the Cinderella of the piece. Other workers, less acquainted with the Alps, have held that the line of volcanoes and its frequent underground equivalent in the denudation series, the line of batholiths, must be afforded a very prominent position in any interpretation of mountain structure. The references that might be

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given in this connexion are legion, among them chapters vi and ix of Daly's recent book *Igneous Rocks and their Origin* (1914). It is not intended here to make a general survey of the subject, but rather to sketch certain conclusions which seem to follow naturally from Suess's presentation of this phase of world geology. The main suggestions offered are as follows:—

1. The arcuate form characteristic of many of the great mountain chains can scarcely have originated through forward movement of these chains, since it characterizes the Aleutian Isles, and other typical examples, where the occurrence of forward movement has been denied.

2. Iceland, with its volcanic arcs, large and small, may well supply a stepping-stone between arcuate fractures of the type so familiar in Scotland, with their accompaniment of ring-dykes, and the vastly greater Aleutian Arc, with its serial volcanoes.

3. The development of volcanic arcs suggests tension rather than compression. The arcuate fractures of an asphalt pavement, the circular cracks of a painted canvas, the miniature landslip fissures on the slopes of a shell crater, all support this contention.

4. Arcuate fractures have often served as guides for the uprise of igneous magma. Volcanic accumulation is the surface manifestation; batholithic intrusion the corresponding subterranean phenomenon.

5. Where, as in Iceland, the magma has been predominantly basaltic, its mobility has favoured volcanic expression. Where, as in the American cordilleras, a vast supply of granitic magma has been drawn upon, or developed, its viscosity has determined intrusion on a magnificent scale. The date and manner of origin of the granite is not involved.

6. The association of a folded cordillera with a volcanic arc suggests the collapse of an unconsolidated axial batholith—a closing together of its two walls and a corresponding compression of its roof. By analogy the same suggestion holds even where the volcanic arc is absent.

In polar regions the cooling of an ice-flow often leads to a development of tension-cracks. Into these, sea-water rises to be frozen over at the surface. A return of warm weather brings the walls together, and the roof of the temporary fissure is driven up to form a ridge. The analogy between such a ridge and the Alps, though obviously very imperfect, seems to merit a passing notice.

7. The cause of a batholithic collapse need not be strictly local. At Kilauea the solid floor of the crater, after ascending gradually for years, will suddenly subside a thousand feet or so, in the course of a few days. On occasion a volcanic outburst at some point on the island accompanies this subsidence, but at other times nothing of the kind is seen, and a submarine eruption is postulated. Perhaps the outpourings of lava in the Brito-Icelandic province had a share in the upheaval of the Alps.

8. Once folding and thrusting have been developed, the outline and almost every other feature of the mountain arc must be profoundly modified. There is not only the revolution in what may be termed the home country of the chain, but also the concomitant

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invasion of neighbouring territories, often on a truly grandiose scale.

9. Obstruction must be admitted as an additional factor in determining the form of a folded range. There may be much truth in the statement that several arcs of the Jura Mountains press forward into the gap furnished by the subsidence of the Rhine "like waves into a bay" (p. 526).

10. Subsidence of a foredeep may, in many cases, have resulted in part from the advance of the cordillera. Or it may, on the other hand, have helped to guide such advance. It is well to remember, however, that at present the Andes are interpreted as furnishing an illustration of back-folding turned eastwards, away from the long belt of subsidence which seems to merit the designation foredeep (p. 497). And also that central subsidences are claimed in well-known cases, such as that of the Lombardy Plain, to which Salomon ascribes the peripheral uprise of the tonalite of Adamello (p. 560).

VI.—SOME AMERICAN PAPERS ON VOLCANOES.

"The Present Condition of the Volcanoes of Southern Italy," by H. S. Washington and A. L. Day. Bull. Geol. Soc. America, vol. xxvi, pp. 375–88, 1915.

A study of the conditions prevailing at Vesuvius, Etna, and the Æolian Islands in the summer of 1914.

Puff Cones on Mount Usu," by Y. Oinouye. Journ. Geol., vol. xxiv, pp. 583–6, 1916.

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