and beauty of these brick, that they are becoming an article of export. Strangers, upon landing here, are surprised that all the brick houses are *painted* of the same color; and their surprise is not abated when informed that they are not painted at all—the color being that of the bricks themselves.*

No fossils of any kind have yet been discovered in these lake deposits. Cylindrical concretions, of an interesting kind, are often found investing the fibres of roots that have penetrated the layers; more commonly the root has decayed, leaving only a small opening through the centre. On breaking across one of these concretions, it is seen to have a concentric structure, as if made of concentric cylinders. Their form is usually cylindrical, tapering at each end. They are much harder than the surrounding mass of clay.

ART. XIII.—*On the Origin of Continents;* by JAMES D. DANA.

IN a paper on the Volcanoes of the Moon, read before the Association of Geologists and Naturalists, in September last,† some suggestions were thrown out with regard to the Origin of Continents, drawn from the condition of a cooling globe. It was observed that the portions of the earth now constituting the great areas of land, were free, or nearly so, from volcanic action, even in the Silurian period: while the oceans appear to have been regions of eruption. Hence it was inferred that contraction must have taken place to the greatest extent over the parts now oceanic, just as any cooling sphere becomes depressed on the side which cools last. This was shown to correspond with the actual history of our globe, inasmuch as an increasing depth in the ocean cavity would necessarily leave more and more land above water in successive epochs, as accords with observations. It was observed that the hypothesis was *farther* borne out by facts: for while it appears that the land has, on the whole, been increasing in extent, even through the tertiary era and subsequent to it, the ocean's bottom has actually subsided several thousand feet within a late period, as shown by the coral islands scattered over the wide Pacific.‡

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* This color is owing to the almost total absence of iron from the clay, and the very small quantity discovered by the usual tests, is sufficient to impart a very delicate cream tint to the bricks.—EDS.

† See this Journal, ii, ii ser., 352.

‡ If we consider that *two hundred islands* have subsided in the Pacific, which, had there been no corals, would have disappeared without a record, we perceive that the comparative absence of islands from the Atlantic, whose waters are, to a large extent, too cold for corals, proves nothing against the hypothesis. On the contrary, so large a bare surface of waters is probable evidence of the disappearance of some points of land by submergence. All existing Atlantic islands are of igneous origin except the Falklands, to the east of Tierra del Fuego.

By reference, therefore, to the principle of unequal contraction, and to those *subordinate* causes of change of level usually appealed to by Geologists, (though treated of commonly as primary in importance,) we may obtain a general view of the origin of the earth's features. I propose at this time to offer a few remarks in illustration of this subject, derived from the features of our own continent, reserving a fuller discussion for another occasion.*

The effects of contraction as a geological cause, though long admitted, have been first brought out in their various bearings by M. Constant Prévost, before the Geological Society of France.† The facts adduced substantiate his views, though, as we believe, with some limitations. They lead us farther to connect the various phenomena, and tell why the ocean and land have their present bounds.

In order to understand the bearing of the facts, we should bring to mind the effects of contraction. The more prominent are as follows:—

1. Depressions, provided the contraction be unequal in different parts.

2. Apparent elevations, as a consequence of the depressions; that is, elevations as compared with the lowest level, or with a body of water occupying the depressions.

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* We may here mention one or two facts in corroboration of the general theory, that the more igneous portions of the globe have contracted most and thereby became submerged. For example, we find the continent of America reduced to a narrow strip of land, just where the great American tract is crossed from east to west by a region of igneous action, not yet entirely extinct; that is, about the West Indies and the adjoining isthmus. This region became thus depressed and submerged, in consequence of greater contraction below; and hence North and South America are nearly disjoined by a broad arm of the ocean. This single instance is the only one, through the continent of America, of volcanic eruptions east of the great western chain of mountains.

Again, the East Indies, another region of perpetual fires, in the earth's history, constitute a cluster of islands separating from Asia the large non-volcanic New Holland, properly a part of a southeastern extension of the continent. Moreover, we may account for the fact that this Archipelago has not farther subsided, so as to become a deep ocean with few islands, on the ground that extensive areas of land, without fires, exist in the midst of the group, Borneo being one example, equalling in extent half the United States, east of the Mississippi. The Indian Ocean, at the same time, bears evidence in its coral islands of a much more extensive subsidence.

† See this Journal, ii, ii ser., 355. While thus mentioning the name of M. C. Prévost, we should remember that the theory of contraction, as a cause of the earth's features, dates as far back as Leibnitz, many of whose speculations in science are proving to be as well founded as the rigid results of his mathematics. And among the geologists of the present day, De la Beche especially has insisted upon this agency as the general cause of the unevenness of the earth's surface, though he stops by stating some of the grand results, without allowing them their full influence as laid down by Prévost. Mr. Lyell, in his *Travels in North America*, has made a partial application of the principle to the Appalachians.

The writer does not claim to have presented any new principle, except it may be the special cause assigned for the oceanic depressions; and whether this holds true, remains for the future to determine.

3. Fissures.

4. Ejection of igneous matter, at times, through fissures.*

5. Upheaval along a line of fissure, the surface adjoining being more or less raised.

6. Upliftings and foldings from lateral pressure.—An arc of the exterior surface being greater than any corresponding arc below the surface, a depression of the hardened exterior, produced by the cooling beneath, would in some instances cause lateral displacements.

7. An *unequal rate* of subsidence over given areas in different periods.—Contraction tends to occasion a strain upon the cooled and unyielding exterior, accompanied generally by a consequent diminished rate of subsidence, or a cessation of it. This strain increases till it results in fractures; and following this crisis, subsidence would for a while be more rapid in rate. The strain, or state of tension, might also occasion elevations in some places, within or without the area; and at the time of fissuring, there might be other upheavals. It follows, hence, that—

a. There would be prolonged intermissions in the subsidence of given areas; and this must have been the fact throughout the history of the globe.

b. There must have been oscillations in the land as compared with a water level, the water at times rising gradually over land that, during a previous period, had emerged; and the reverse.

c. There might be in the same epoch, under such circumstances, an unequal retreat of the ocean from the coasts of different continents, or a rise in one place and a retreat in others: for the changes by contraction are supposed to have been every where in progress at the same time, and throughout different in character and extent.

d. Changes of level may in some cases have been *gradual*, and in other cases *paroxysmal*; for the opening of large fissures would often be of the latter character.

8. In an elliptical area of contraction, there will be two systems of fissures at right angles with one another, as follows from the calculations of Wm. Hopkins, Esq.† But if the area is bounded on one side by a region participating but little in the contraction, the effects would be most decided on the borders of such a region; and they would consist in extensive fissures ranging along

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* Prévost argues that all eruptions of igneous matter have arisen from the collapsing of the surface upon the fluid of the interior, which is thereby pressed out. This is a probable effect of the contraction going on, though it seems to be extended too far to include with it all the eruptions of volcanoes.

† Trans. Camb. Phil. Soc., vii, 22.

the area, and an attending swelling of the surface, or else a rising of the strata into folds by lateral pressure.*

The effects of lateral pressure might in many parts be local or of very limited extent. A contracting area might be made up of several separate areas of contraction not acting together upon any particular line. Even supposing a whole quarter of our globe to exert laterally all the force possible, by a uniform contraction continued till the surface was depressed eight miles in depth, the whole effect would be equivalent to a lateral dislocation of only twelve miles. And in this calculation, we make no allowance for upliftings over the contracting area, which would diminish the action; nor for a diminution of breadth in the surface of the area, which diminution must be going on if the surface is losing heat. In the remarks which follow relating to this point, America, therefore, is not instanced as an example of what *must every where* have happened, but of what *has here* happened.

The foregoing are the obvious effects of contraction. A *Prince Rupert's drop* (a drop of unannealed glass) may be referred to for farther illustration. The exterior, owing to its cooling first, is under strong tension, and each particle (or section) in the surface, presses laterally upon its neighbor like a stone of an arch upon the one adjoining; and hence the effect of a simple scratch in causing it to break to pieces, explosively. The earth, had it cooled uniformly over the whole exterior, (and were it made of a uniform homogeneous material,) would have been in the same circumstances, the whole crust being under immense tension, yet every where balanced, and therefore not apparent; but cooling unequally, the same actual amount of force has been exerted, yet at different periods, producing, in different parts and in different periods, fractures, depressions and upliftings.

We comprehend the effects described more clearly if we remember, as we ought, the common statement, that the highest

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* With regard to the *folding* of strata by lateral pressure, the theory was first presented by Sir James Hall, (Trans. Roy. Soc. Edinb., vii, 85,) and the injection of granite, coupled with the elevation of the land, was suggested by him as a probable source of the pressure in the instances he mentions. Scrope, reasoning on this subject, says, in his work on volcanoes, published in 1825, "There is reason to conclude that in most instances, the raised strata, particularly those which were only partially indurated, have been contorted and bent into repeated foldings, so as to give the appearance of frequent alternations of different series of strata to what is in reality but the replication of the same original series."—p. 201. De la Beche applies the theory to the structure of the Alps, (Geol. Researches, 129,) the possibility of which application was suggested by Sir James Hall.

Authors have generally followed Sir James Hall in considering that besides the lateral pressure, pressure *from above* is essential to this result. But since the soft strata are *inelastic*, and moreover, in themselves *are of vast weight*, we may conclude that there is sufficient vertical pressure independent of any foreign source. A small hand model appears to be as suggestive of error in this case, as a child's model of a bridge to the inexperienced bridge builder.

mountains of the earth are about equal in comparative altitude to the thickness of the cracked varnish on a twelve inch globe.

We remark, again, that we exclude none of those causes of elevation usually recognized, which facts show to have been in operation, though allowing them only a subordinate place.

From these explanations, we proceed to the application of them.

If the reader will place before him a good map of North America, he will perceive at once the effects which have been alluded to exhibited on a grand scale, on both sides of the continent. On the *Atlantic* side, the Appalachians, from Maine to Georgia, consist of rock strata, which have been variously folded up into ridges, as has been made out with great beauty and fullness by Professors W. B. and H. D. Rogers.* These folds are in several series, but are nearly uniform or parallel in position. As should be expected from the nature of the cause, the plications are more frequent and abrupt on the side of the chain nearest the ocean, and gradually die out westward just beyond the limits of the Appalachians. As another result of proximity to the contracting area, the rocks on the eastern side have been most altered by fire. To so great a degree has the heat operated, (which escaped by the opened cavities and fissures, and was distributed laterally by the aid of the contained and incumbent waters,) that it is difficult in New England to distinguish the true igneous rocks from those that are metamorphic.

On the *Pacific* side of the continent, we observe the Rocky Mountain range rising with a gentle swell from the coast. From the mouth of the Kansas to the top, and on the opposite or western side, the average slope is hardly twelve feet to the mile.† The summit is about eight thousand feet high. But there are ridges which add five or six thousand feet to the chain: these form a crest to parts of the range, but are not properly the range itself, though often so recognized. The Rocky Mountains appear, then, to be another effect of contraction, viz. a gradual swelling of the surface, accompanied by fissures and dislocations over its area. These dislocations are very marked in the sandstone, just east of the summit. Thus each great oceanic depression, the Atlantic and Pacific, has its border range of heights thrown up by the very contraction which occasioned the depression; and between lies a vast plain, scarcely affected at all by these changes, the great central area of the continent. This view is farther sus-

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* Trans. of the Assoc. of Amer. Geol. and Nat., 1840, 1842, p. 474, and this Journal, xliii, 177; xliv, 359.

† See the section of the region between the mouth of the Kansas and Fort Vancouver, by Captain Fremont, in the Report of his Exploring Expedition to the Rocky Mountains in 1842, and to Oregon and North California in 1843, 1844. Printed by order of the Senate of the United States, Washington, 1845.

tained by finding that the effects of fire are most apparent on the ocean side of the mountains, precisely as about the Appalachians, yet to a more remarkable extent.* Indeed, there are no remains of volcanoes, or their ejections, to the east of the summit; while to the west, the country of Oregon is in many parts buried beneath basaltic or other volcanic rocks, and several existing volcanic cones have been described. Still farther, we observe a second, a third, and even a fourth parallel range of heights from the summit of the mountains to the coast; and the third (the Cascade range) rivals the Rocky Mountains in the height of some of its snowy peaks. Vast fissures were opened to the fires below, as these ranges indicate, and some of the vents have not yet ceased action.† Here, then, are the natural effects of proximity to a region of contraction—the Pacific—in which the remains of igneous action every where abound.

It has been well established that the Appalachian folds or plications were made since the coal period, for the coal beds are enclosed in the folds;‡ and the rising of the Rocky chain was also subsequent to that era. The effect of contraction in producing these elevations, was therefore comparatively little felt in the very earliest ages, when the surface of the depressed (or igneous) portion was itself somewhat yielding, but subsequently, when it had become stiffened to a considerable depth by cooling. There appears hence to be a perfect harmony between the results and the causes adduced.

If these conclusions are correct, we must give up the popular idea (at least as a general theory) of the elevation of mountains by a force below causing at the time an irruption of igneous matter; for the irruption is in general an effect of a very different action, as has been urged by Prévost. This may be as true of the Urals, as of the Rocky Mountains and Andes.

Even the trap dykes of New England and New Jersey, whose general course corresponds with that of the Appalachians, may be a result of the contraction in progress subsequent to the coal

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* The same is the general character of the Andes. In an account of the geology of Chile, M. I. Domeyko says, speaking of the Andes in the latitude of Copiapo, "En regardant du côté de l'Ouest, on voit un bouleversement complet dans le terrain souleve: des failles et déchirements, des escarpments à pic, des stratifications contournées et interrompues. En portant ensuite la vue du côté de l'est, on voit des pentes douces, des bancs de rochers presque horizontaux et rarement interrompus."

"Tout annonce que le principal mouvement qui survint à l'époque de la formation des Andes arriva *du côté de l'Ouest*, c'est-à-dire du côté où une ligne d'escarpments qui marquent le rivage actuel de l'Ocean depuis le Cap Horn jusqu' aux Montagnes Rocheuses, continue à se soulever d'une manière lente et à peine perceptible, au mugissement des bruits souterrains et sous l'influence des tremblements de terre repetes."—*Annales des Mines, iv ser.*, ix, 413. *2nd. liv.*, 1846.

† Granites may have been the earlier products; but the existing volcanic mountains have basalts and trachytes for their surface rocks.

‡ W. B. and H. D. Rogers, Trans. Assoc. Amer. Geol. and Nat., 1840–1842, p. 522.

era. The dip of the new red sandstone accompanying them is probably another effect. The Ozark mountains, forming a line parallel with the Appalachians, beyond the Mississippi, may be referred to the same system of changes.

The economical advantages belonging to the features of North America that have thus originated, are most remarkable, and this view of their origin gives them increased interest. The Silurian rocks indicate that before the coal period the region was comparatively level, and lay mostly beneath the sea. As it emerged it was still dripping with water, so that, under a climate peculiarly genial, coal vegetation might have grown luxuriantly. But had it continued thus flat to a later period, it would have had but small streams, and probably, for want of a mountain barrier to intercept the *drying* Pacific winds, the desert regions of the west would have traversed the land, as Sahara has spread over Africa. As if to prevent these results, and give a vastness scarcely equalled to its resources, the land was raised into mountains on either coast, those of the west, where the barrier was most needed, ascending even to the regions of perpetual snows. The whole interior is now enclosed by the Rocky Mountains on the one side and the Appalachians on the other, and a thousand streams are set in motion over the wide land from either bound, all to contribute to a common trunk, the great highway of the country. Thus the largest possible extent of intercommunicating inland waters has been secured; and for the same reason a great part have been made to flow so nearly on a plain as to afford navigation almost from one end of the territory to the other, and extend their fertilizing influence over the whole surface. A similar result has been produced on the narrow ocean side of the main chains by the succession of parallel coast ranges; for the waters have been compelled to flow far north and south between these ranges, and fertilize an extended country before the sea was reached. Thus the noble Columbia, with its wide spread tributaries, was made for Oregon; and in the same manner were formed the Willammet, the Sacramento, and the Joachim, which run in long courses between the Cascade and Coast ranges of heights. Thus on the Atlantic side, we have the Shenandoah and other head waters to the Potomac, and at the north, a Hudson, Connecticut and Merrimack flowing in parallel lines.

Note.—In connection with this article, it should have been earlier mentioned that the theory of "secular refrigeration" has been presented with much force, in many points of view, by W. W. Mather, in this Journal, vol. xlix. p. 284, (1845), and the foldings of the Appalachians are attributed by him to this cause.