

*The Rev. Wm. Stukeley M. D. F. R. S. to
the President, concerning the Causes of
Earthquakes §.*

Read April 5.
1750.

AMONG all the Appearances of Nature, which are the Subjects of the Inquiries of the *Royal Society*, none would more sensibly affect the Minds of contemplative Persons than that of an Earthquake; especially to us in this Country, where they so seldom happen.

When I had the Honour last *Thursday** to lay my Thoughts upon it before the *Society*, I found that some worthy Members had not fully enter'd into my Way of Reasoning; nor with that Seriousness so awful a Subject requir'd: Therefore I judg'd it necessary to treat upon it in a more diffusive manner; and with some further Considerations relating to that Argument.

Among the numerous Accounts received here, and Observations upon the Manner of it, I judg'd it became the *Society* to inquire into the Cause of so extraordinary a Motion, of which we could not have form'd a proper Idea, had we not repeatedly both seen and felt it.

The Notions of the Antients are sufficiently known; nor have the Moderns any-way improv'd upon them, any further than by some chymical Mixtures. The vulgar Opinion goes no deeper than some Caverns, not far below the Surface of the Earth; wherein are ingender'd Vapours, Ex-
P p p p plosions,

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* See this *Transf* p. 641.

plosions, Fermentations, and Fires from inflammable Minerals; that cause these Convulsions of the Surface.

I shall not pretend to deny, that there may be such Vapours, Fermentations, Rarefactions, and inflammable Substances, and actual Fires, in the Bowels of the Earth, and that there may be some Caverns under-ground, as well as we find some few above-ground, *Pool's Hole*, *Okey Hole*, and the like, in mountainous Countries. We know there are hot Springs running continually, and *Vulcano's* frequently belching out Flames and Smoke; and to these, most probably, some smaller Earthquakes are owing.

But these Matters are very rare, much rarer than Earthquakes, both as to Time and Place. *Vesuvius* in *Italy*, and in that Part of it abounding with Mines of Sulphur; *Aetna* in *Sicily*; some on the great *Andes* Mountains in *America*, and the like. The Scarcity of them, in my Opinion, is so far from being a Proof of the general cavernous State of the Earth, that it strongly proves the contrary.

How many thousand Acres of Coal-Mines, Stone-Pits, and the like, do they daily work in *England*, and have done for Ages? I have been myself 100 Yards deep in a Salt-Rock. I have walked half a Mile lengthwise, directly into the Earth, and under the Bed of the Ocean: But we never hear, from the many Hundreds of Thousands of Workmen in this kind, of the cavernous State of the Earth.

On the contrary, by their hard Labour they confess it far otherwise. Nor have we any Reason, in *England*, to believe there are great Mines of Sulphur, and

and inflammable Minerals: Nor, if there were, could they burn, and cause Convulsions of the Earth, unless there were proper Cavities, and Conveyances of Air; as in Coal-Pits, when set on fire.

But even from these Coal-Pits, when fired, do we ever find any thing like an Earthquake produc'd? Nor did we observe, in these two last Earthquakes, any Fire, Vapour, Smoke, or Smell; or any kind of Eruption in the least, in so great a Struggle of the Surface, as affected a Circle of 30 Miles in Diameter.

Indeed this Consideration alone, of the Extent of this Surface, is sufficient to overthrow any Supposition of Earthquakes being *chiefly* owing to subterraneous Vapours. For it cannot possibly be imagined, that such can have so immense a Force, as to act upon that Compass instantaneously, all at once, and never break Ground, so as to be discoverable to Sight or Smell. Many Accounts we have of a little Fire-ball bursting in the Air, at a great Distance, and instantly propagating a sulphureous Smell all around it for Miles.

If the Motion of a Superficies of 30 Miles Diameter was owing to Fumes and Vapours, we ought reasonably to find some great Discharge of them, like a Coal-Pit fired: The Operation of it ought to be Hours and Days in Continuance, not instantaneous: And the Evaporation of such a Quantity of inflammable Matter requires a long time to evacuate itself.

There is another Argument, which, in my Opinion, utterly overthrows these Suppositions; and that is, a due Consideration of Springs. If we would

form any tolerable Idea of the Nature of Springs and Fountains perpetually flowing, and *that* (generally speaking) from the Creation of the World, we must needs conceive, that GOD ALMIGHTY has laid their Pipes and Canals in the Earth, like as he has planted the Veins, Arteries, and Glands, in an animal Body; and that likewise they are more and more ramify'd, as they nearer approach the outward Shell of the Earth.

The Workmen in Coal-Mines, and the like, never fail to meet with the Veins of Springs every-where: They that dig for Wells seldom fail of finding Water every-where. The Colliers are obliged to drain, at very great and continual Expence. A Circumstance not very favourable to subterraneous Fires.

Now it is apparent enough, that the Hypothesis of Vapours, and subterraneous Fermentations, Explosions, and Eruptions, being the Cause of Earthquakes, must absolutely ruin the whole System of Springs and Fountains, where-ever it has once been. But this is quite contrary to Fact; even where an Earthquake has been repeatedly; for Instance, from home.

On *Wednesday, April 6. 1580.* about 6 in the Evening, just such another Earthquake was felt in *London*, and around it, as these two we have seen. Another, exactly similar, in 1692. In all these 4, no Houses thrown down, nor any Springs disturb'd thereby: No sensible Eruptions or Smells.

These Considerations I apply only to this little inconsiderable Space of a Circle of 30 Miles Diameter. But what is that to the Appearance of some Earthquakes

Earthquakes we read of in History? In the Year of our Lord 17. no less than 13 great and noble Cities of *Asia minor* were destroy'd in one Night. The Fact is so notorious, that some Persons here present have seen a vast Block of white Marble, now standing near *Naples*, being the Pedestal of a Coloss Statue of *Tiberius* the Emperor, having carv'd on it, in *Basso relievo*, the *Genius's* of all those Cities, with their Names; which were rebuilt by that Emperor.

Without going so far, we may see another Evidence of it, a Coin of that Emperor struck upon it, with this Inscription,

CIVITATIBUS ASIAE RESTITVTIS.

I have one of them in large Brass, which was found at *Colchester*.

The Compass of this Earthquake may be reckon'd to take up 300 Miles in Diameter. How can we possibly conceive the Action of any subterraneous Vapours to produce such an Effect, as instantaneously to demolish all these Cities? And that such an Accident should never happen after? How comes it to pass, that the whole Country of *Asia minor* was not at the same time destroy'd, its Mountains renvers'd, its Fountains and Springs broken up, and ruin'd for ever, and its Rivers disannull'd? Instead whereof, we find nothing suffer'd, but those Cities; no kind of Alteration in the Surface of the Country, which remains the same to this Day.

From these Considerations therefore, I cannot persuade myself easily to enter into the Opinion of Earthquakes *generally* arising from pent-up Vapours
and

and Eruptions. I know there are many strange Relations of Effects of subterraneous Fires, told by Authors that deal pretty much in the Marvellous, and whose Minds were prepossessed with those vulgar Notions. My Conceptions of the Matter are deriv'd from the more general Appearances, and what we have seen and felt ourselves.

After we have treated this Argument in a superficial View, we must go a little deeper. If we would consider things like Philosophers, let us propose to ourselves this Problem;

Where is the Power to be plac'd, that is requir'd to move a Surface of Earth 30 Miles in Diameter?

To answer this, consult the Engineers, and those that make Mines in the Sieges of Towns. They will acquaint us, that the Effect of Mines is produc'd in Form of an inverted Cone: And that a Diameter of 30 Miles in Base, will require an Axis of 15 or 20 Miles to operate upon that Base, so as to shake it, at least. So that the Vapours, and whatever Power we propose to operate upon that Base, according to the foregoing Hypothesis, in order to form the Appearance of an Earthquake, must be 15 or 20 Miles deep in the Earth.

But what Mind can conceive, that any natural Power is able to move an inverted Cone of solid Earth, whose Base is 30 Miles in Diameter, and Axis 20? Or, was it possible, would not the whole Texture of that Body be quite disturb'd and shatter'd; especially in regard to its Springs and Fountains? But nothing like this is ever found to be the Consequence of an Earthquake, tho' fatal to Cities.

Apply

Apply this Reasoning to the Earthquake of *Asia minor*; and this vigorous Principle must lie at least 200 Miles deep in the Ground. Enough to shew the Absurdity of it. A Cone of 300 Miles Diameter at Base, and 200 Miles Axis; I dare be bold to say, that all the Gunpowder made since its Invention, put together, would not be able to move it. How much less would pent-up Vapours?

And, could it be admitted as a thing possible, will any one be persuaded, that such a subterraneous Tumult, of so vast an Extent, will be no-ways injurious to the internal System of Springs and Fountains? We may as well imagine, that we may stab a Man 100 times, and never touch a Vein or Artery.

In an Age when Electricity has been so much our Entertainment, and our Amazement; when we are become so well acquainted with its stupendous Powers and Properties, its Velocity, and instantaneous Operation, thro' any given Distances; when we see, upon a Touch, or an Approach, between an Electric and a Non-electric, what a wonderful Vibration is produced, what a Snap it gives, how a lambent Flame breaks forth, how violent a Shock; is it to be wonder'd at, that hither we turn our Thoughts, for a Solution of the prodigious Appearance of an Earthquake?

It is every body's Observation, that there never was a Winter like the past, for Warmth and Dryness, Thunder and Lightning very uncommon then; for Coruscations in the Air, justly thought to be electrical; especially for that call'd *Aurora australis*; the Wind continually South and South-west, and that without Rain, which is unusual. This State
of

of the Atmosphere had continued 5 or 6 Months, before the first Earthquake: Is it not hence reasonable to conclude, that the Earth must, especially in our Region, be brought into an unusual State of Electricity; and, consequently, wanted nought, but the Approach of a non-electric Body, to produce the Snap, and the Shock of Electricity?

That the Earth was in that vibratory and electric State, we have further Reason to conclude, from the very extraordinary Forwardness of all the vegetable World with us. Every one knows, that, at the End of *February*, all sorts of Garden-stuff, Fruits, Flowers, Trees, were as forward as, in other Years, in the Middle of *April*. Conformable to which, Experiments abundantly shew us, that electrifying of Plants quickens their Growth; for the same Reason as in Animals it quickens the Pulse.

Any solid Matter is capable of being put into a State of Electricity; such as iron Guns; and the more so, by reason of their Solidity: And in proportion to it is the Greatness of the Snap, and of the Shock; and a kind of lambent Flame issues out of the Point of Contact; and likewise somewhat of the sulphureous Smell. So that if both Flame and Smell were discernible in an Earthquake, it is to be found, without going to the Bowels of the Earth.

As to the immediate Cause of this wonderful Appearance of an Earthquake, I hinted that it was owing to a non-electric Body coming near or touching the Earth, when in its electrify'd State; which may be a Shower of Rain: And the learned Dr. *Childrey* observes, that Earthquakes always succeed

Rain:

Rain. A sudden Tempest of Rain, in the Time of a great Drought.

At the same time that the Force of Electricity in Solids is as the Quantity of Matter, we see most evidently, that Water is equally forcible in strengthening and conducting it, and that in proportion to its Quantity: Which very much justifies my Observation, that most frequent Earthquakes have fallen upon maritime Places. And I find the same Observation is made before me by *Acosta* and *Dolittle*, who wrote on that in 1692. and others. In the dreadful Catastrophe of *Port-royal*, it is notorious, that its Violence was chiefly near the Sea: And even in those so lately felt by us, they were sensibly more violent toward the River, than further from it. And in that Earthquake in *England*, in 1692. (which was very much like that we are treating of) there were no Houses thrown down, nor Persons kill'd; but it reach'd more particularly *Sandwich*, *Deal*, *Dover*, *Sheerness*, *Portsmouth*, and the maritime Parts of *Holland*, *Flanders*, and *Normandy*.

In this that happen'd last *Sunday* at 6 in the Evening at *Bath*, it was felt particularly at *Portsmouth*, the whole *Isle of Wight*, and *Jersey*.

If we look into antient History, we find, in the 197th Year before Christ, an Earthquake shook terribly the Isle of *Rhodes*, damag'd many Cities, and some were swallow'd up.

17 Years before Christ, many Cities in the Isle of *Cyprus* were destroy'd.

6 Years before Christ, the Isle of *Coos* was most vehemently afflicted.

During the *Peloponnesian* War among the *Greeks*, the Isle of *Delos* was afflicted, and the most beautiful Temple of *Apollo* thrown down.

Soon after, the City of *Lacedæmon* was totally destroy'd.

A. D. 79. three Cities in *Cyprus* were overthrow'n.

A. D. 182. the City of *Smyrna* was ruin'd.

Constantinople has often suffer'd; particularly in 1509. 130000 People overwhelm'd.

A. D. 1456. in the City of *Naples* 40000 People were destroy'd.

In 1531. at *Lisbon*, 1400 Houses were thrown down, and near as many shatter'd.

In the Time of *Valens* the Emperor, a terrible Earthquake happen'd in *Crete*, whereby 100 Cities were destroy'd.

But Instances enough, to shew what I aim'd at, that maritime Places are most subject: Which is no contemptible Argument in Favour of Electricity; when both the Solid of the Earth, and the Quantity of the Water, concur to make the Shock exactly, as in common electrical Experiments.

The Gardener in the *Temple* Garden observ'd the Sound to roll from the Water-side toward *Temple-Bar*, before the ceasing of the Nodding of the Houses; just as the electrical Snap precedes the Shock. Others, that write upon Earthquakes, commonly observe, that the Noise precedes the Shock. But it is obvious it must be quite the contrary, did the Concussion depend on a subterraneous Eruption.

We may well enough expect, that bursting Vapours, and subterraneous Explosions, should disperse
every

every thing that happen'd in their Way into the Air: But, in my Apprehension, it is not possible for us to imagine any thing to produce such a Vibration as we felt, but Electricity.

Several People felt Pains in their Joints, Rheumatism, Sicknefs, Head-ach, Pain in their Back, Colic, hysteric and nervous Disorders, for the whole Day after, and longer (especially weak Constitutions), exactly as upon Electrification; and to some it has prov'd fatal.

Upon this Principle alone can we account for the Fishes leaping out of the Ponds; or a sort of Thump felt at the Bottom of a Boat. Nay, we are told of Earthquakes felt at Sea, far distant from Land: Which are easily solv'd by an electrical Shock impress'd upon the Water: But we cannot easily see Vapours and Fires residing at the Bottom of the Ocean.

From electrical Vibration alone can we account for that Observation of Springs and Fountains being no-ways damaged after an Earthquake. I doubt not but they run more plentifully at that time; just as the Blood circulates quicker upon Electrification.

From Electrification only can we account for this Particular. The Walls of *Westminster Hall* are of no mean Thickness; yet those that sat with their Backs to it, during the Shock, all relate that it seem'd to push toward them with great Force. So in that of 1692. at *Deal*, the Wall of the Castle, which is of an extraordinary Thickness and Strength, shook so much, that the People living in it expected it would have fallen on their Heads.

For thus the Force of the electrical Shock is proportionate to the Quantity of the Solid. And were

Fumes and lambent Flames seen to issue out of the gaping Ground on these Disasters, as Relations tell us, we justly may pronounce them to be purely the Effect of Electricity.

It must be accounted no inconsiderable Argument in Favour of our Hypothesis, that the Northern Regions of the World are little subject to Earthquakes, in comparison of the Southern; where the Warmth and Driness of the Air, so necessary in Electricity, is common. Notwithstanding that we have a Vulcano in *Iceland*, yet we hear not of Earthquakes frequent in that Latitude of the Globe.

But whether our Conjectures upon this important Affair be well founded or no, it certainly becomes a Christian Philosopher, whilst he is investigating material Causes, to look up to the moral Use of them; for, in reality, every thing in the whole World was ultimately made for that Purpose. And of all the great and public Calamities which affect us Mortals, Earthquakes claim the first Title to the Name of Warnings and Judgments; none so proper to threaten, or to execute Vengeance: Nor has any other those annexed Terrors, so much of the unusual, the unavoidable, and the horrible Apprehension of being crush'd to Death, or buried alive.

I cannot but insist upon my former Observation to be just, that Earthquakes proclaim themselves to Mankind in this Light; because peculiarly directed to great Cities and maritime; abounding with Wealth and Luxury. It would be childish to make a long Recital of Particulars from History; for had we no other sort of Notices of Earthquakes? Look upon those two Shocks we have felt. We own, that

that *Hamstead-Heath*, and *Finchley-Common*, and *Kennington Common*, may have been affected with it; yet it is notorious, that *London* was the Centre; the Place to which the Finger of GOD was pointed.

XXXIV

Some Considerations on the Causes of Earthquakes. By the Rev. Stephen Hales, D. D. and F. R. S.

Read April 5.
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AS the late Earthquakes in *London*, and some other Parts of *England*, have roused the Attention of Mankind, to consider the Causes of them, both in a religious and natural View: And as in a religious View they have been considered by the Bishop of *London*, in his excellent Letter to the Clergy and People of *London*, which has been received with general Approbation: So I shall here give a short Account of what seems to me to be a probable natural Cause of them.

But I must first obviate an Objection of some serious well-meaning People, who are apt to be offended at any Attempts to give a natural Account of Earthquakes; which, but rarely happening in these more northern Parts, are apt to be looked upon as the more miraculous. But it ought to be considered, that the ordinary Course of Nature is as much carried on by the Divine Agency, as the extraordinary and miraculous Events. God sometimes changes the Order of Nature, with Design to chastise Man for his Disobedience