Some considerations on the causes of earthquakes. Which were read before the Royal Society, April 5, 1750 / By Stephen Hales.

SOME

CONSIDERATIONS

ON THE

CAUSES

OF

EARTHQUAKES.

Which were read before the ROYAL SOCIETY, APRIL 5, 1750.

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SOME

CONSIDERATIONS

ON THE

Cauſes of Earthquakes.

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* and *Weſtminſter*, which has been received with general Approbation: So I ſhall here give a ſhort Account of what ſeems to me a probable natural Cauſe of them.

But I muſt firſt obviate an Objection of ſome ſerious well-meaning People, who are

apt

apt to be offended at any Attempts to give a natural Account of Earthquakes, which but rarely happening in theſe more northern Parts of the World, 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 and Follies, natural Evils being graciouſly deſigned by him as moral Goods. All Events are under his Direction and fulfill his Will. On the other Hand, there are ſome who make light of Earthquakes, becauſe they are capable of being accounted for by natural Cauſes. But the Hand of God is not to be overlooked in theſe Things, under whoſe Government all natural Agents act, eſpecially ſuch rare and unuſual Events as Earthquakes; God uſes all Creatures to be the Inſtruments of his Will, natural and moral Agents are all under his Direction. When he inflicts a Famine on a Nation, it is not the leſs the

Hand

Hand of God, becauſe we know the natural Cauſes of it, *viz.* great Drought and unkindly Seaſons. *Fire and Hail, Snow and Vapours, and ſtormy Wind fulfill his Word*, Pſal. cxlviii. 8. Infectious Air, peſtilential Diſeaſes, and Earthquakes, however occaſioned by natural Cauſes, are under the Divine Influence.—He not only orders and directs the Operations of Nature; but alſo influences the Actions of moral Agents, turning as he pleaſes, the Hearts of the Governors of the Nations, ſo as frequently to chaſtiſe Mankind, by that ſevere Scourge, and great Diſgrace of human Nature, *War*. Earthquakes are not therefore to be ſlightly regarded, becauſe we think we can give a probable natural Account of them, neither ought we on that Account to encourage our ſelves to go careleſsly on in wicked Courſes. If national Judgments do not overtake us, yet it cannot be long before we ſhall come into the ſeverer Puniſhments of our future State. And *tho' Sentence againſt an evil Work is not ſpeedily executed, tho' a Sinner do evil an hundred Times, and his Days be prolonged*;

prolonged; yet ſurely I know it ſhall not be well with the wicked, Eccles. viii. 11, 12, 13.

It may not be improper, on this Occaſion, to mention another conſtant and uninterrupted Plague, in which, of late Years, we have been and are like to continue Sufferers, in common with many other Nations. A Plague of all others, the greateſt that ever befel unhappy Man; it being by far the moſt deſtructive, not only of the Lives, but alſo of the Morals of Mankind, both a natural and a moral Evil. I mean fermented diſtilled Spirituous Liquors, of all Denominations: Did God Almighty deſtroy as many by Earthquakes, as are yearly deſtroyed by diſtilled Spirituous Liquors, which is probably about a Million of Perſons in a Year, all over the World; how great a Terror and Conſternation would it cauſe every where! But alas! with what Unconcernedneſs, with what Calmneſs and even Complacency, is this enormous both natural and moral Evil received and even foſtered among us? Inſomuch, that it is now by

a juſt

a juſt Judgment, become the Curſe and the Puniſhment of the World, even the greateſt that ever befel Mankind. Notwithſtanding which this inchanting Syren ſo bewitches and infatuates the Nations, that it ſpreads its baleful Influence far and wide, making yearly farther and farther Devaſtations, both of the Lives and Morals of Mankind, and even debaſing the Breed of Man.

As to the Affair of Earthquakes, particularly that which happened at *London*, *March* 8, 1749-50. about 20 Minutes before Six in the Morning, I being then awake in Bed on a ground Floor, near *St. Martin's in the Fields* Church in *London*, very ſenſibly felt the Bed heave, and conſequently the Earth muſt heave too; there was an obſcure ruſhing Noiſe in the Houſe, which ended in a loud Exploſion up in the Air like that of a ſmall Cannon. The whole Duration from the Beginning of the Earthquake to the End was 3 or 4 Seconds of Time. The Soldiers who were upon Duty in *St James's Park*,

and others who were up, ſaw a blackiſh Cloud, with conſiderable Lightning, juſt before the Earthquake began; it was alſo very calm Weather.

And in the Hiſtory of Earthquakes it is obſerved that they generally begin in calm Weather, with a black Cloud; and when the Air is clear juſt before an Earthquake, yet there is then often Signs of plenty of inflammable ſulphureous Matter in the Air, ſuch as *Ignes fatui*, or Jack-a-Lanterns, and the Meteors which are called falling Stars.

Now I have ſhewn many Years ſince, in the *Appendix* to my *Statical Eſſays*, Experiment 3. page 280. the Effect that the Mixture of a pure and a ſulphureous Air have on each other, *viz.* by turning the Mouth downwards into a Pail of Water, a Glaſs Veſſel of a Capacity ſufficient to hold about two Quarts, with a Neck about twenty Inches long, and two Inches wide; then by putting under it in a proper Glaſs Veſſel with a long narrow Neck, a Mixture

of

of *Aqua fortis*, and pounded *Pyrites*, viz. the Stone with which Vitriol is made; there will be a briſk Ferment, which will fill the Glaſs with reddiſh ſulphureous Fumes, which by generating more Air than they deſtroy, will cauſe the Water with which the whole Neck of the Glaſs Veſſel was filled, to ſubſide conſiderably. When the reddiſh ſulphureous Air in the upper Part is clear, by ſtanding two or three Hours; if then, the Mouth of the inverted Glaſs is lifted out of the Water, ſo as to let the Water in the Neck of the Glaſs fall out; which ſuppoſing it to be a Pint, an equal Quantity of freſh Air will ruſh in at the Mouth of the Neck of the Veſſel, which muſt immediately be immerſed in the Water. And upon the Mixture of the freſh Air, with the then clear ſulphureous Air, there will inſtantly ariſe a violent Agitation between the two Airs, and they will become from tranſparent and clear, a reddiſh turbid Fume of the Colour of thoſe Vapours, which were ſeen ſeveral Evenings before the late Earthquakes. During which Effervеſcence a Quantity of

Air nearly equal to what freſh Air was let in, will be deſtroyed, which is evident by the riſing up of the Water in the Neck of the Glaſs almoſt as high as before. And if after the Effervescence of the mixed Airs is over, and become clear again, freſh Air be admitted as before, they will again grow reddiſh and turbid, and deſtroy the new admitted Air as before; and that after ſeveral repeated Admiſſions of Air. But after each Readmiſſion of freſh Air, the Quantity deſtroyed will be leſs and leſs, till no more will be deſtroyed. And it is the ſame after ſtanding ſeveral Weeks, provided in the mean Time too much freſh Air had not been admitted. Now I found the Sum total of the freſh Air thus deſtroyed to be nearly equal to the firſt Quantity of the ſulphureous Air, in the inverted Glaſs.

Since we have in this Experiment, a full Proof of the briſk Agitation and Effervescence, which ariſes from the Mixture of freſh Air, with Air that is impregnated with ſulphureous Vapours, which are raiſed from ſeveral

mineral

mineral Subſtances, eſpecially from the *Pyrites* which abound in the Earth, may we not with good Reaſon conclude, that the irkſome Heat which we feel, in what is called a cloſe ſultry Temperature of Air, is occaſioned by the inteſtine Motion, between the Air, and the ſulphureous Vapours which are exhaled from the Earth? which Effervescence ceaſes as ſoon as theſe Vapours are equably and uniformly mixed with the Air, as happens alſo in the Effervescences and Ferments of other Liquors. The common Obſervation therefore, that Lightning cools the Air, ſeems to be founded on good Reaſon; that being the utmoſt and laſt Effort of this Effervescence.

May we not hence alſo with good Probability conclude, that the firſt kindling of Lightning is effected by the ſudden Mixture of the pure ſerene Air above the Clouds, with the ſulphureous Vapours which are ſometimes raiſed in plenty, immediately below the Clouds; the moſt dreadful Thunders being uſually when the Air is very

very black with Clouds, it rarely thundering without Clouds? Clouds ſerving in this Caſe, like the above mentioned inverted Glaſs, as a Partition between the pure and ſulphureous Airs, which muſt therefore upon their ſudden Admixture, thro' the Interſtices of the Clouds, make, like the two Airs in the Glaſs, a more violent Effervescence, than if thoſe Airs had without the Intervention the Clouds more gradually intermixed, by the conſtant more gradual Aſcent of the warmer ſulphureous Vapours from the Earth, a Deſcent of the cold ſerene Air from above. And tho' there was no luminous Flaſh of Light in the Glaſs, yet when ſuch ſudden Effervescence ariſes, among a vaſt Quantity of ſuch Vapours in the open Expanſe of Air, it may, not improbably, acquire ſo rapid a Velocity, as to kindle the ſulphureous Vapours, and thereby become luminous.

And ſince from the Effects that Lightning is obſerved to have on the Lungs of Animals, which it often kills, by deſtroy-

ing

ing the Air's Elaſticity in them, as alſo from its burſting Windows outwards, by deſtroying the Air's Elaſticity on the outſide of thoſe Windows. Since, I ſay, it is hence probable, that the ſulphureous Fumes do deſtroy a great deal of elaſtick Air, it ſhould therefore cauſe great Commotions and Concuſſions in the Air, when the Air ruſhes into thoſe evacuated Places, which it muſt neceſſarily do with great Velocity. Dr. *Papin* has calculated the Velocity, with which Air ruſhes into an exhauſted Receiver, when driven by the whole Preſſure of the Atmoſphere to be at the Rate of 1305 Feet in a Second of Time, which is at the Rate of 889 Miles in an Hour, which is near 18 Times a greater Velocity than that of the ſtrongeſt Storms, which is eſtimated to be at the Rate of 50 Miles in an Hour *. Hence we ſee that an outrageous Hurricane may be cauſed by deſtroying a ſmall Proportion of the Elaſticity of the Air of any Place in reſpect to the Whole. No wonder

* *Lowthorp*'s Abridgment, Philoſ. Tranſ. v. 1. p. 586.

then

then that ſuch violent Commotions of the Air ſhould produce Hurricanes, and Thunder-ſhowers, eſpecially in the warmer Climates, where both the ſulphureous and watry Vapours, being raiſed much higher and in greater Plenty, cauſe more violent Effects.

Monſieur *de Buffon*, in his natural Hiſtory and Theory of the Earth, mentions black dark Clouds in the Air, near the tempeſtuous *Cape of Good Hope*, and alſo in the Ocean off of *Guinea*, which are called by the Sailors the *Ox's Eye*, which are often the Fore-runners of terrible Storms and Hurricanes; whence it is to be ſuſpected, that they are large Collections of ſulphureous Vapours, which by deſtroying ſuddenly a great Quantity of the elaſtick Air, cauſe the ambient Air to ruſh with great Violence into that Vacuity, thereby producing Tempeſts and Hurricanes. And off the Coaſt of *Guinea* they have ſometimes three or four of theſe Hurricanes in a Day, the Fore-runners of which, are theſe black ſul-

phureous Clouds; with a ſerene clear Air and calm Sea, which on a ſudden turns Tempeſtuous on the Exploſion of theſe ſulphureous Clouds. And at *Jamaica* they never had an Earthquake when there was a Wind to diſperſe the ſulphureous Vapours.

In like manner we find in the late Earthquakes at *London*, and in the Accounts of many other Earthquakes; that before they happen there is uſually a calm Air with a black ſulphureous Cloud, which Cloud would probably be diſperſed, like a Fog, were there a Wind; which Diſperſion would prevent the Earthquake, which is probably cauſed by the exploſive Lightning of this ſulphureous Cloud; being both nearer the Earth than common Lightnings, and alſo at a Time when ſulphureous Vapours are riſing from the Earth, in greater Quantity than uſual, which is often occaſioned by a long Series of hot and dry Weather. In which combined Circumſtances the aſcending ſulphureous Vapours in the Earth may probably take fire, and thereby cauſe an

Earth Lightning, which is firſt kindled at the Surface and not at great Depths, as has been thought, whoſe Exploſion is the immediate Cauſe of an Earthquake. *

I am ſenſible that it may ſeem improbable that the aſcending ſulphureous Vapours in the Earth ſhould thus be kindled; but ſince they are continually aſcending thro' the Pores of the Earth, more or leſs, for many good and uſeful Purpoſes, it is plain there is room for them to paſs; beſides, as Monſ. *de Buffon* ſays, Naturaliſts have obſerved perpendicular and oblique Clefts in all kinds of Layers of Earth, not only among Rocks, but alſo in all Kinds of Earth, that have not been removed, as is obſervable wherever the Earth is opened to any Depth. Now theſe Clefts are cauſed

* It is in the like Manner that thoſe Meteors which are called falling Stars, are ſuppoſed to kindle into a Flame at the upper Part of a ſulphureous Train, which is kindled downwards into a Flame, in the ſame Manner as a freſh blown out Candle is inſtantly lighted from another Candle held above it at a Diſtance, in the ſulphureous inflammable Smoke of it.

by the drying of the ſeveral horizontal Layers of Earth ; and will alſo be conſiderably the wider in long dry hot Seaſons, which are uſually the preparatory Forerunners of Earthquakes. And the Exploſion of the ſulphureous Vapours may probably widen them more.

It is very obſervable that even Volcano's, in the Opinion of *Borelli* and other Naturaliſts, began firſt to kindle near the Surface and Top of the Mountains, and not by the fermenting of the Pyrites and ſulphureous Vapours in the Caverns, in the lower Parts of the Mountain. Monſ. *de Buffon* ſays, that Earthquakes are moſt frequent where there are Volcano's, ſulphureous Matter abounding moſt there ; but that tho' they continue burning long, yet they are not very extenſive. But that the other ſort of Earthquakes, which are not cauſed by a Volcano, extend often to a great Diſtance. Theſe are much longer Eaſt and Weſt, than broad North and South ; and ſhake a Zone of Earth with different Degrees of Force in

different Parts of their Courſe, *viz.* in proportion to the different Quantities of explosive ſulphureous Matter in different Places. Theſe kind of Earthquakes are obſerved to be progreſſive, and take Time to extend to the great Diſtances, ſometimes of ſome Thouſands of Miles. They are an inſtantaneous Exploſion in every Place, near the Surface of the Earth; and therefore do not produce Mountains and Iſlands near other Iſlands as Volcano's ſometimes do.

The Earthquake in *London*, *March* 8. was thought to move from Eaſtward to Weſtward. Monſ. *de Buffon* mentions an Earthquake at *Smyrna* in the Year 1688. which moved from Weſt to Eaſt, and in the Earthquake at *London* on the eaſtern Side. And accordingly it was obſervable that the reddiſh Bows in the Air, which were ſeen ſeveral Days before that Earthquake, aroſe in the Eaſt, and proceeded Weſtward. It was obſerved after the Earthquake at *Smyrna*, that the Caſtle-walls, which run from Eaſt to Weſt, were thrown

down, but thoſe from North to South ſtood. And that the Houſes on Rocks ſtood better than thoſe on Earth *. It was obſerved that the Waters turned foul the Day before an Earthquake at *Boulogne* in *Italy*, which was probably occaſioned by the Aſcent of great Plenty of ſulphureous Vapours thro' the Earth.

As to the hollow rumbling Noiſe which is uſually heard in Earthquakes, it ſeems not improbable, that it may be occaſioned, by the great Agitation, that the Electrical Æthereal Fluid is put into, by ſo great a Shock, of a large Maſs of the Earth. For if the little Motion of a ſmall revolving Glaſs

* Monſ. *de Buffon* relates, that the Vibrations of the Earth in Earthquakes, have commonly been from North to South, as appears by the Motion of the Lamps in Churches; which makes it probable that tho' the Progreſs of the Earthquake at *Smyrna* was from Weſt to Eaſt, yet the Vibrations of the Earth might be from North to South, and thereby occaſion the falling of the Caſtle-walls which run from Eaſt to Weſt; but not thoſe which run from North to South. A probable Argument that as the freeſt Paſſage, ſo the greateſt Exploſions were made in the Clefts of the Earth, which run Eaſt and Weſt, which would make the Vibrations North and South.

Globe,

Globe, can excite it to the Velocity of Lightning, and that with a Force ſufficient to kill Animals: How much greater Agitation may it probably be excited to, by the exploſive Force of an Earthquake? The Exploſion of a Cannon in St. *James*'s Park, is obſerved to electrify the Glaſs of the Windows of the *Treaſury*. And what makes it ſtill more probable, is, the Analogy that there is between them in other reſpects: For as the electrical Flaſh ruſhes with the Velocity of Lightning, along the moſt ſolid Bodies, as Iron, *&c.* and as I have ſeen it run only on the irregular gilding of Leather, ſo, ſuch ſolid Bodies are obſerved to be the Conductors of Aereal Lightning, which rends Oaks in Pieces, and has been known to run along, and melt an Iron Bell Wyre in two Sides of a Room, *&c.* And accordingly it was obſerved in the great Earthquake in *Jamaica*, that the moſt tremendous roaring was in the rocky Mountains. And in the late Earthquake of *March* 8, in *London*, the lowdeſt Exploſions were thought to be heard, near ſuch large Stone

Buildings,

Buildings, as Churches, with lofty Steeples and Spires. I who lay in *Duke's Court* near *St. Martin's Church*, and was awake all the Time of the Earthquake, plainly heard a loud Exploſion up in the Air, like that of a ſmall Cannon, which made me conjecture that the Noiſe was owing to the ruſhing off, and ſudden Expanſion of the electrical Fluid at the Top of *St. Martin*'s Spire; where all the electrical Effluvia which aſcended up along the larger Body of the Tower, being by Attraction ſtrongly condenſed, and accelerated at the Point of the Spire, as they ruſhed off made ſo much the louder expanſive Exploſion.

F I N I S.