

The history and philosophy of earthquakes from the remotest to the present times: collected from the best writers on the subject. With a particular account of the phaenomena of the great one of November 1st 1755, in various parts of the globe / By a Member of the Royal Academy of Berlin [i.e. John Bevis].

Contributors

Bevis, John, 1693-1771.
Royal Academy of Berlin.

Publication/Creation

London : J. Nourse, 1757.

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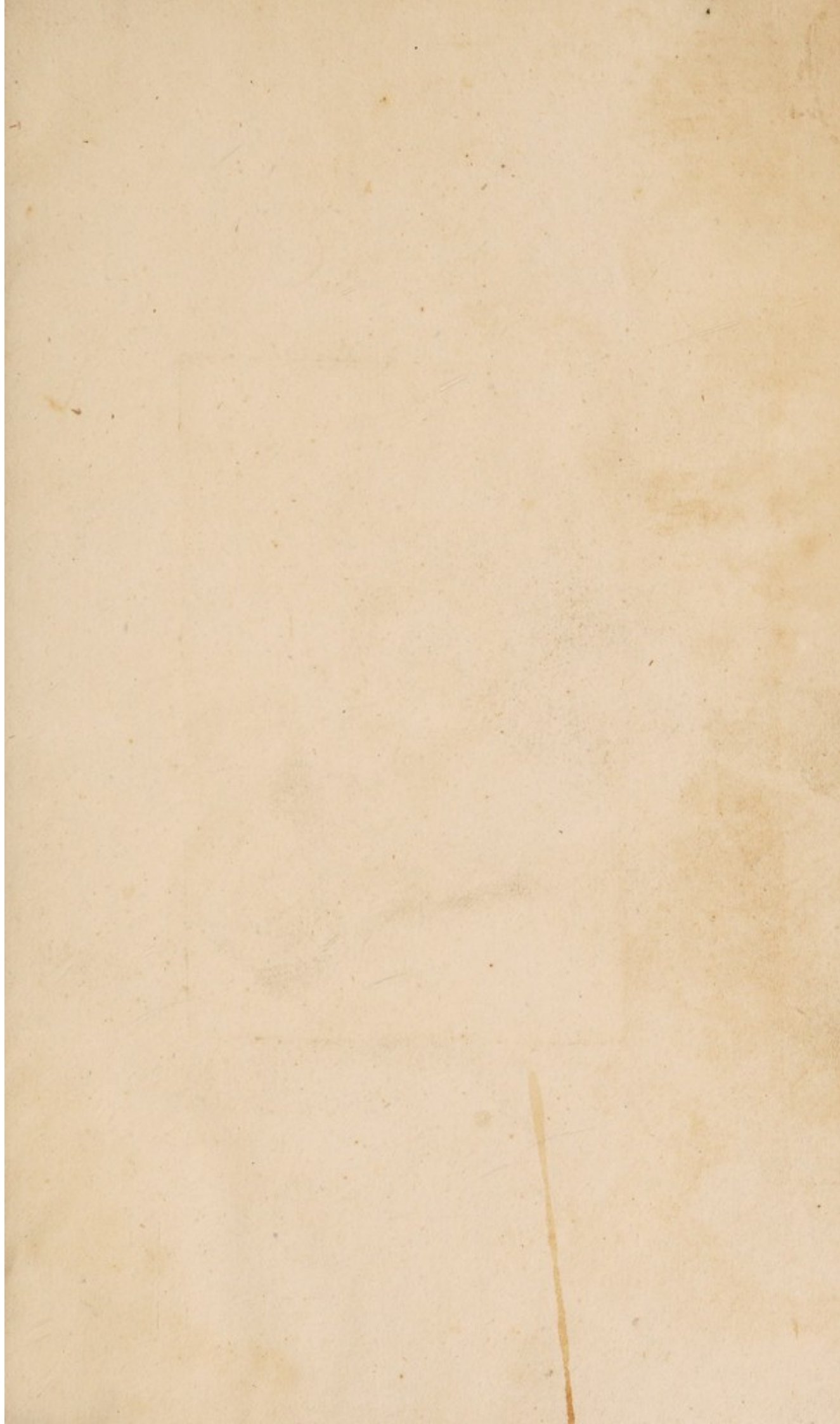
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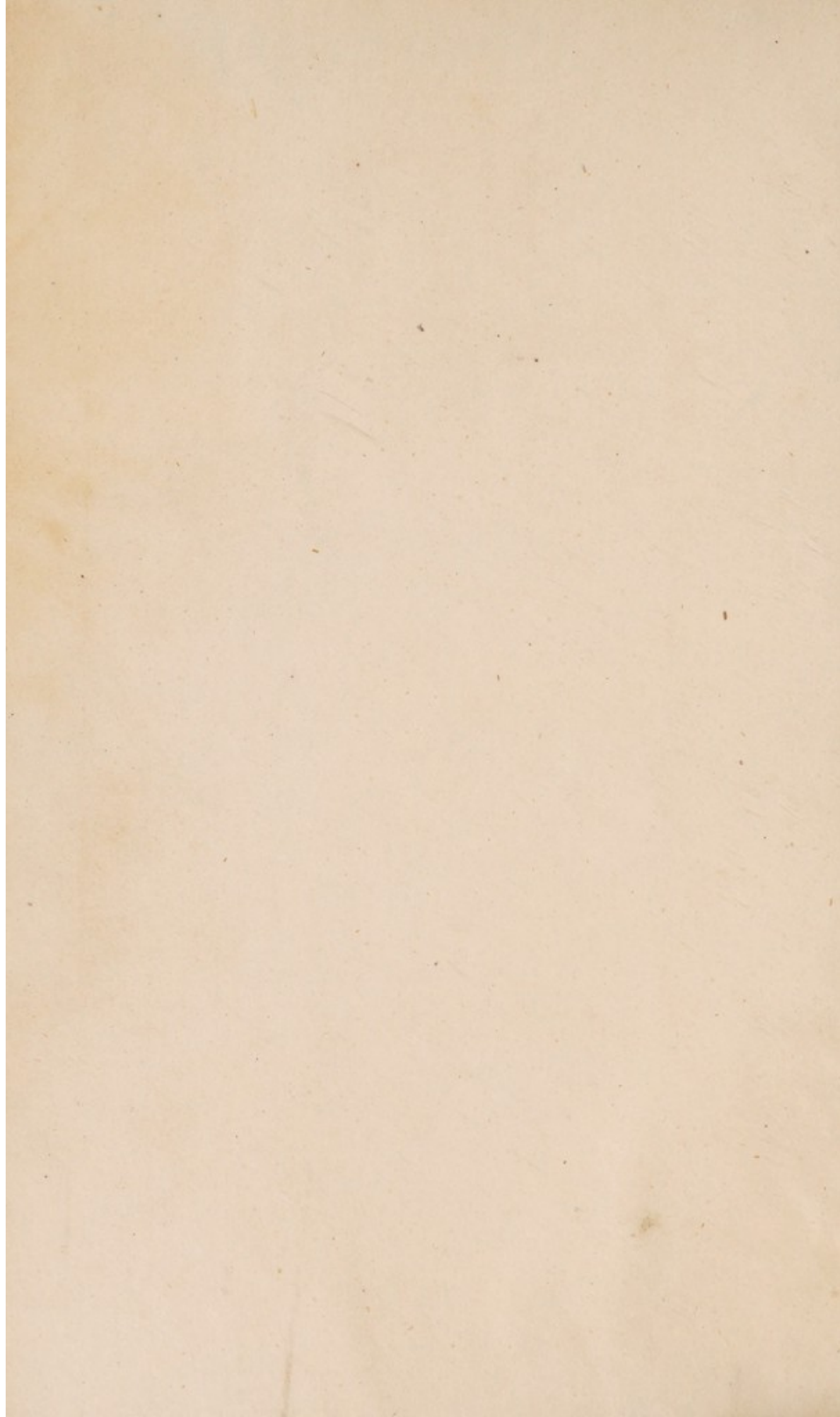
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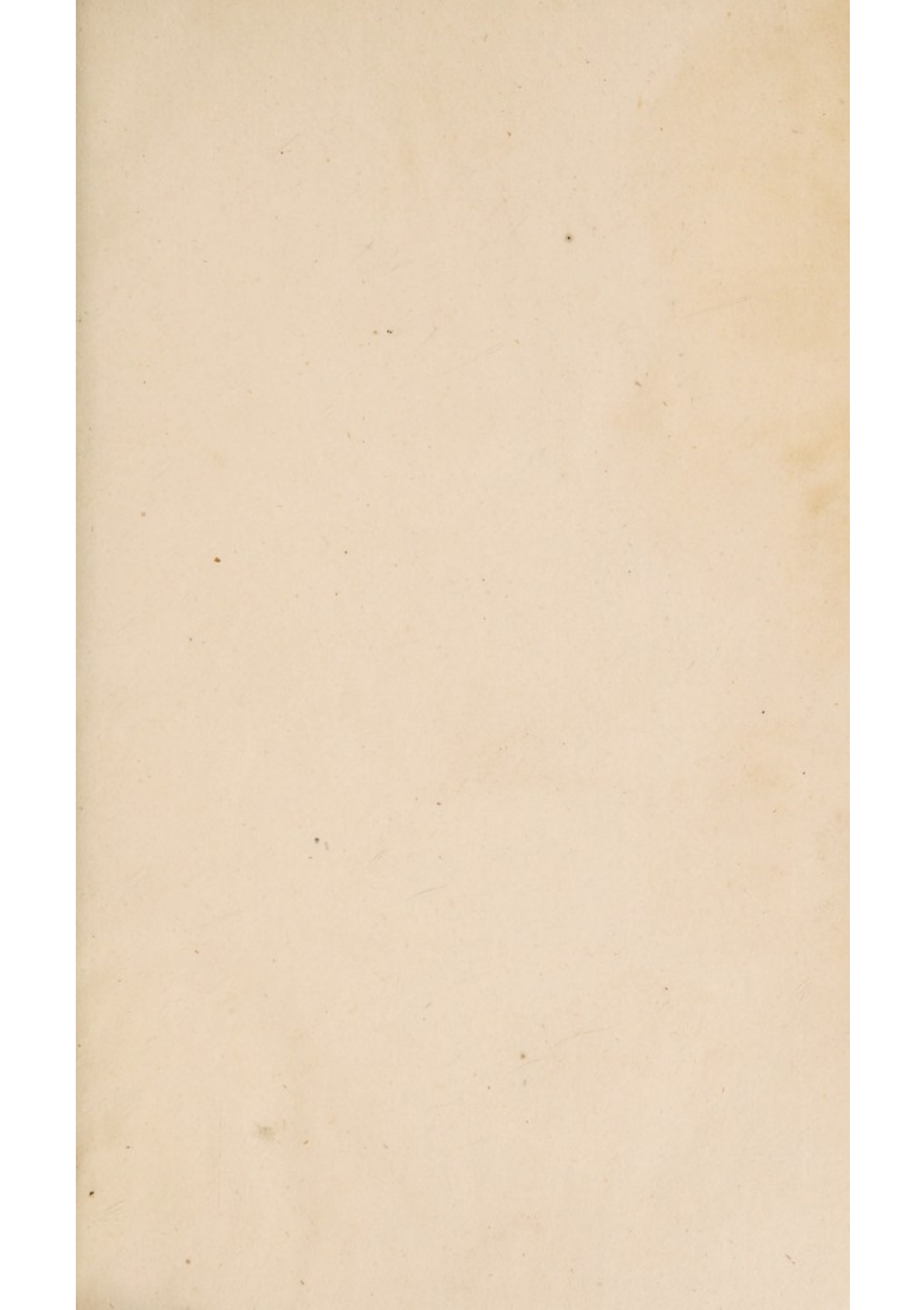
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BEVIS, John









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T H E
HISTORY *and* PHILOSOPHY
O F
E A R T H Q U A K E S,
F R O M T H E
Remotest to the present Times:
Collected
From the best Writers on the Subject.

With a particular account of
The Phænomena of the great one of NOVEMBER
the 1st 1755, in various Parts of the Globe.

By a Member of the ROYAL-ACADEMY of *Berlin*.

Philosophiæ genus empiricum quod in paucorum experimentorum angustiis et obscuritate fundatum est.---Tum vero de scientiarum progressu bene fundabitur, quam in historiam naturalem recipientur et aggregabuntur complura experimenta, et observationes, quæ in se nullius sunt usus, sed ad inventionem causarum et axiomatum faciunt. VERULAM. Nov. Organ.

A most general help to discovery in all kinds of philosophical inquiry is, to attempt to compare the working of nature, in that particular which is under examination, to as many various mechanical and intelligible ways of operations, as the mind is furnished with.

Dr. HOOKE'S *Method of improving Natural Philosophy.*

L O N D O N,
Printed for J. N O U R S E over-against *Katherine-street*
in the *Strand*, MDCCLVII.

P R E F A C E.

THE memorable earthquake which spread desolation along the *Atlantic* coast in 1755, and the late frequency of such commotions, in a lesser degree, all over *Europe*, put the editor of these sheets upon exhibiting succinct accounts of the like events in past times, with the sentiments of the best naturalists as to their causes: In the course whereof he has retained entirely the facts, arguments and conclusions of the authors from whence he has extracted his collections, and that almost in their own words; without ever presuming to criticise any hypothesis, much less to obtrude one of his own.

Thus, he hopes, he has furnished a repertory of all that has been written of earthquakes and their causes, to be read over at leisure, or readily consulted, by the help of a very copious index.

In the annexed account of the last great earthquake he has chosen a kind of alphabetical arrangement, for the easier turning to its phænomena in particular places; all which, he has very carefully collected from the *Philosophical Transactions* of the Royal Society, and other literary memoirs and authentic vouchers; and which, as our very sagacious Dr. HOOKE rightly observes, *should ever be registred as soon as the observations occur; because of the frailty of the memory, and the great significancy there may be in some of the meanest and smallest circumstances.*

A L I S T

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- I. *A Methodical Account of Earthquakes* by JOH. CHRIST. STURMIUS, Professor of Physics and Mathematicks at Altorff in Germany, Page 1
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A

Methodical Account

O F

EARTHQUAKES.

PHÆNOMENA, or FACTS.

Phæn. **O**N the 7th of July 1686 about day-break, between two and three in the morning, a great part of Germany and the neighbouring parts of Italy felt a tremulous commotion. At *Altorff* and the nearest towns of *Bavaria* and *Suevia*, *Ratisbon*, *Memmingen*, *Nordlingen*, with many others, the inhabitants were awakened out of their sleep, and grievously terrified by the rocking of their beds and jarring of their windows. In other places, as *Inspruck* and *Venice*, the tottering edifices threatened immediate destruction: And at *Hall* the walls, with many towers and stately buildings were shattered, and several of the inhabitants buried or oppress'd in the ruins; the

consternation causing most of the rest to betake themselves to the open fields, where they continued wandering about for some days, under the most terrible apprehensions.

A dismal and horrible phænomenon of nature this! though not unfrequent at other times and places; and therefore highly deserving the consideration of natural philosophers, in order to investigate its true causes.

May we not justly exclaim with the eloquent *Seneca*,^a “ When the world is shaken, and the
 “ solid parts of it drop asunder, when the fixed
 “ bases of the rocks are rooted up, where can
 “ we hide our heads in safety? Where fly for
 “ refuge, when the globe is falling to pieces? If
 “ the stage which supports us, and on which ci-
 “ ties are erected, gives away, what can admi-
 “ nister help? Or how can comfort be found
 “ where our fears oppose our flight? Walls may
 “ repel an enemy, and lofty towers stop the pro-
 “ gress even of armies: Havens may afford suc-
 “ cour in a tempest, and houses shelter from
 “ storms and wind: Conflagrations overtake not
 “ the haste of those that fly them: Subterrane-
 “ ous vaults and caverns can secure against thun-
 “ der and lightning, a small quantity of earth
 “ bring proof against this celestial fire, and whole
 “ countries were never ruin’d by it: A pestilence
 “ may destroy the citizens, yet leaves the city
 “ standing: But an earthquake is a wide-wast-
 “ ing, implacable, unavoidable calamity!”

^a Lib. vi. quæst. nat. cap. i.

Phæn. II. That a natural earthquake never extended over the whole globe, is according to *Stobæus*^b, an observation of *Plato*, which *Aristotle* also asserts in very significant terms^c. The same thing is remarked by *Metrodorus*, and other ancient philosophers mentioned by *Plutarch*^d, and *Seneca*,^e who at the same time explode the opinion of *Thales*, and with reason; that the earth may be liable to fluctuations, because it swims in water, and that those are earthquakes.

Seneca's words are, "If the waters supported the earth, it would be liable to universal concussions, and it would be a greater wonder that it should ever be at rest, than if it were perpetually in motion." Sure enough it must be shock'd throughout, and not in any part alone; for no ship can be tossed by halves. We conclude then, that there is no such thing as an universal earthquake, but that they are all particular or partial.

Phæn. III. As to the difference of earthquakes happening at different times, or of one and the same with regard to various places; at some times, and in some particular places, they occasion a latitudinal and, in a manner, horizontal trembling

^b *Eclog. phys. cap. 1. Nullo recensitorum ibi modorum moveri terram statuit, sed ἐν τῷ πανταχόθεν ἰσοτάλῳ κειμένην μένειν ἀκίνητον. τόπος δὲ αὐτῆς κατ' ἀραιότητά σαλένεσθαι.*
h. e. *Eam in æquabilissimo undequaque loco positam immotam manere, loca autem ejus aliqua rariora concuti.*

^c *Lib. ii. meteor cap. 47. καὶ ἂν μέρος δὲ γίγνεται οἱ σεισμοὶ τῆς γῆς, καὶ πολλάκις ἐπὶ μικρὸν τόπον.*

^d *Lib. iii. de placit. cap. 15.* ^e *Nat. quæst. lib. vi. cap. 6.*

in some particular part of the earth, and its incumbent cities and buildings, with a certain degree of concussion or shock, which, by a peculiar name, *Aristotle* calls τρόμον, and *Seneca*, tremor. Sometimes and in certain places, the impetus is impress'd upwards, rather in a perpendicular direction. *Aristotle* calls it σφύγμα, or *Pulsus*, and *Seneca*, succussion. This makes the earth to rock, like a ship at sea, which *Seneca* calls inclinatio, and *Garcæus*, from *Pliny*, arietatio, especially when the inclination is from side to side; and then it is also named ἐπικλίνης, inclinator. In all these cases whole buildings, and even cities are frequently subverted; and sometimes, especially in the second case, the earth is violently burst asunder (ῥήξις) or projected aloft, (βράσις) and according to *Ammianus Marcellinus*, Brasmutias, or collapses inwards, the χασμαλίας of *Marcellinus*, and the labes, ruina, &c. of others.

Phæn. IV. These distinctions are to be found in *Seneca*^f, and *Pliny*^g, who likewise give their names^h. As also does *Ammianus Marcellinus*ⁱ. The earthquake we mentioned, *Phæn.* I. affords an example of these varieties. Here at *Allorf*, and in the neighbouring parts, we found the tremor: At *Venice*, *Inspruck*, &c. they felt the pulse, or succussion; at *Hall* the subversion. *Gassendus* takes notice of one wherein nothing but a tremor was sensible, on the 13th of January 1617. On the

^f Lib. vi. quæst. nat. cap. 4.

^g Lib. ii. hist. nat. cap. 80.

^h *Senec.* cap. 21. *Plin.* cap. 82.

ⁱ Lib. xvii. cap. 13.

6th of *April* 1580, all the *Low Countries* were shaken with a *succussion* which was felt as far as *Paris*, and *York* in *England*: And the town of *Artric* was rocked to that degree, that stones were forc'd out of the walls of towers and churches^k. *Gaspar Schottus* was at *Rome* when another happened there in 1654^l. The symptoms of the *inclination*, and the *arietation* are described by *Seneca*^m, and *Pliny*ⁿ, which latter gives in the same place an account of the clashing together of two huge mountains with a most horrible noise, and of their receding asunder again: And the former relates a thing very strange, of the parting of the square marble stones in the pavement of a bath, through whose interstices quantities of water issued and returned, and of their settling in close order again. The same authors give many instances of *subversions* and *ruins*; as at *Nicomedia* in *Bitthynia*, where a vast number of persons were buried under fallen edifices^o. *Garcaeus*^p gives the names of twelve cities of *Asia*, which *Seneca*^q and *Pliny*^r relate to have been subverted in one night, in the reign of *Tiberius*: *Tacitus*^s affirms the same, with this addition, that those who attempted to escape into the fields, the gaping earth swallowed up, and that whole mountains quite subsided, and new ones arose out of the plains: We read in *Seneca*^t of a *commotion* throughout *Campania*, which

^k *Meterranus*. lib. x. ^l *Mechan. hydr.* p. 62. ^m *Lib.* vi. cap. 31. ⁿ *Lib. ii.* cap. 82. ^o *Ammian. Marcellin.* lib. xvii. cap. 13. ^p *Meteor.* p. 304. ^q *Cap. i.* ^r *Lib. ii.* cap. 84. ^s *Lib. ii. annal.* ^t *Lib. supr. cit.*

shook down several towns about *Naples*. *Johnston*^u transcribes *Cambden's* account of a miserable desolation which happened in *England* in 1571, on the 21st of *March*: *Gassendus*^w describes, from *Fernerius*^x; the memorable stroke given, in one quarter of an hour, to all the towns, mountains and rivers near *Lima* in *Peru*, on the 25th of *November* 1604: And lastly, *Athanasius Kircher*^y affirms that he was an eye-witness, not without great peril to himself, of the sad disaster which befell the fine town of *Euphemia* in *Calabria*, being sunk as it were in the twinkling of an eye, and covered over with a lake of stinking water, the latter end of *March* 1638; who adds that earthquakes ravaged up and down for fourteen days together about that time.

Phæn. V. After these instances of past times, it may be proper to give a succinct account of some late ones, out of my collections at large, from the most approved *Dutch, French, Italian* and *German* writers. The *Rimini* gazettes related that on the 18th of *April* 1662, during divine service, a terrible earthquake threw down twelve churches, and shattered other parts of that city; that it continued 'till the next *Saturday* and *Sunday*, whereby thirty one palaces and publick edifices were demolished, and above 700 persons killed, besides many more sadly maimed; and that the neighbouring cities of *Faro, Pesaro, Sini-*

^u Admir. meteor. cap. 7.

^w Animadvers. in Diog. Laert. x. p. 1049.

^x Hydrog. lib. xv. cap. 18.

^y Mund. subterr. lib. ii,

gaglia, &c. were not without a share of the calamity. The *Journal des Sçavans* for the month of *May* 1678, mentions a terrible earthquake which began *February* the 5th 1663, about half an hour after five in the evening, and raged throughout all *Canada* 'till *July* following, tho' but for a quarter or half an hour together, almost every day or night. Its effects were horrible, as mountains clashing together, and tumbling partly into the river *St. Lawrence*, and partly removed to vast distances with their trees standing upon them. Letters from *Cornelius Frank*, president and counsellor at *Ternate*², to *William Maetsuyker*, counsellor at *Banda*², dated *August* 22, 1673. make mention of two unheard of miracles; the one of the bursting asunder and dispersion of the very high mountain *Gammac-norra*, with a violent earthquake, and so prodigious an ejection of ashes, that on the 21st of *May*, being *Whit-Sunday*, the air became thereby so darkened, that people could scarcely discern one another: The other of a second and most stupendous earthquake which the inhabitants of *Ternate* were surprized with in the night of the ensuing *August*, about a quarter of an hour after eleven: It split the mountain of *Ternate* quite from the bottom to the top on the south side, and levelled the strong palace of King *Mandarfabas* with the ground. At the same time the sea raged so furiously, that all the vessels in the port were in the utmost danger of being lost, and the shocks were still violent

² One of the *Molucca* islands.

² Another island in the *Indian* sea.

on the first of *September*, when other letters came away. An *Italian* letter of *Antonio Bulifon*, to the captain general of the kingdom of *Sicily*, contains a narrative of an earthquake at *Naples* on *Whitsun Eve*, *June* the 5th, 1688, so powerful that it shook even the foundations of that city. The houses at first seemed to be lifted up, and then instantly were rocked backwards and forwards with inconceivable violence, and to that degree, that in some towns the bells rang of themselves; that particularly belonging to the clock of *St. Angelo*, was thrown a full palm out of its gudgeon. What greatly augmented the consternation was a horrible rumbling all the while, as if the world were turning upside down. In the month of *June* 1690 news arrived from the island of *St. Christopher* in *America*, and likewise from *Charles Town*, of several stone houses being overset by an earthquake, and then swallow'd up; in some places, of the earth rising up in large hills, and of the sinking of trees into chasms 7 or 8 feet wide in others. The *Jesuits College*, and all other free stone buildings in *St. Christophers* were razed to the ground. Letters from *Naples* and *Rome* of the 3d and 7th of *February* 1693, brought advice of the ruin of the cities of *Catanea*, *Agosta*, and *Syracuse*, in *Sicily*; also of *Reggio*, and several other places in *Calabria*; and that as to the rest of *Sicily*, near one half was overturned, above 100000 souls being lost under the ruins of no less than 27 great towns. That at *Agosta*, *Taormino*, *Syracuse* and *Catanea*, there are scarce any marks of the walls and fortifications to be seen, in which last city alone, at least 18000 persons perished;
and

and that the head of the neighbouring mountain, at least 600 feet high, sunk within its hollow, and left a gap six *Italian* miles broad.

Phæn. VI. These shocks and burstings of the earth are accompanied with most hideous crashes and bellowings, called by the author of the book *de Mundo* *μυκητῖαι σεισμοὶ*, and by *Ammianus Marcellinus*, *Mycematia*: The like noises also frequently precede a shock, and have been known to happen even when no sensible commotion followed. *Pliny* says, “ They are preceded or accompanied with a dismal sound, which sometimes resembles the lowings of cattle, sometimes the outcries of men, and at others, the din of clashing arms ^b.” And *Aristotle* gives the like account, adding, with *Pliny*, ὅτι καὶ ἄνευ σεισμῶν, ἤδη πᾶ γεγόνασιν ὑπὸ τὴν γῆν ^c. *Vesuvius*, *Ætna*, and *Hecla* confirm this; the last of which is said to utter such a plaintive kind of sounds, that many of the credulous inhabitants take them for the doleful wailings of wicked sinners in hell. During the 11 days earthquake in *Sicily* in the year 1537, the whole island was perpetually alarmed with horrible bellowings, and claps resembling the discharge of large ordnance ^d; and *Kircher* affirms the ^e like of *Calabria* ^e.

Phæn. VII. Through these chasms and rendings of the earth, it is no uncommon thing for flames and smoaky exhalations to ascend, and disperse themselves to considerable distances; and

^b Lib. ii. cap. 80. ^c Lib. ii. meteor. t. 46. ^d *Varen.*
lib. i. geograph. cap. 10. prop. 5. ^e Loco. supr. cit.

with them stones, and torrents of a kind of melted metal are often ejected. Sometimes these are fore-runners of the shock, and they frequently continue after it, especially from the mouths of volcano's^f. *Tacitus* speaking of the great earthquake which happened in the reign of *Tiberius*, remarks *effulsisse inter ruinas ignes*^g. So in the earthquake which we said raged eleven days together in *Sicily*, the earth opened with a mighty chasm, from whence fire and flames issued with such violence, that every thing within the distance of five leagues from *Ætna* was totally burnt up in the space of four days: A short time after which the basin threw out an inconceivable quantity of fire, sparks and ashes^h. *Aristotle* produces some examples of ancient timesⁱ. And *Hieron. Welschius*, one of a later date, of which himself was an eye-witness. “On the 16th of December 1631, when a very great earthquake was felt, and terrible thunderings were heard at *Naples*, a little before the next day-break *Vesuvius* was seen to blaze out, being burst open in several places, notwithstanding the thunder and earthquake still continued^k.” But besides *Ætna*, now *Monte Gibello*, and *Vesuvius*, or *Vesuvius*, now *Montè* or *Montagna di Somma*, *Hecla* in *Island*, and others, several more ignivomous mountains or volcano's have been discovered within a few centuries. The *Sulfero* hill, or rather the field fum-

^f *Senec.* lib. vi. nat. quæst. cap. 4. ^g *Loc. citat.* ^h *Varen.* ubi supr. ⁱ *Meteor.* lib. ii. t. 42. ^k *Itiner.* sui. p. 80.

ing and burning with sulphur near *Puzzoli*, called the *Solfatara*, as likewise *Stromboli* or *Strongylus*, according to *Welschius*¹, was quite burnt out, fallen flat, and covered with the sea about 30 years ago, before which it was surrounded with 8 other sulphury hills (by the ancients called *Insulæ Æoliæ*, and *Vulcaniæ* and *Lipariæ*,) one of which the same *Welschius* saw burning, together with *Strongylus*^m. Several have been found in the islands of the *East Indies*. One for example in *Java* burst out in the year 1586, with a violent eruption of burning sulphur. Mount *Gonnapi* in one of the *Bandan* islands, after it had continued burning seventeen years, was then rent asunder, with an impetuous discharge of stones and sulphureous matter. In the *Molucca* islands are many volcano's, the chief of which is the *Caminus Ternatensis* before spoken of: All of which *Varenius* recounts at large from *Maffei*; and adds, that one of prince *Maurice's* islands, near the *Molucca's*, is frequently visited with earthquakes and eruptions of fire and ashes. The like sort of volcano's also abound in *Japan* and its neighbouring isles, and in the *Philippines*; but most of all in *America*; nor have they been wanting, tho' at this time extinguished, in the *Flanderkin* islandsⁿ.

Phæn. VIII. Sometimes vast torrents of water flow out at these ruptures, forming lakes and ri-

¹ Itiner. p. 104. ^m Itiner. p. 195. ⁿ See *Varen. geog. lib. I. cap. 10. prop. 5. Athan. Kircher. Mund. subterranean. lib. ii. cap. 11. lib. iv. sect. i. cap. 5 and 7. and præf. cap. 3. also Bern. Cæsius lib. i. de mineral. cap. 8. sect. 2.*

vers where there were none before; and drowning whole cities and islands, which is confirmed by *Seneca*^o. And *Aristotle* affirms, “that waters have burst forth from the ground at the time of earthquakes^p”. And the treatise *de Mundo* says, “Some earthquakes have opened fountains where there were none before^q”. For examples of this kind read *Kircher* on the stinking lake which covers the city of *Euphemia*^r, and *Gassendus*, and *Furnerius* on the *Peruvian* earthquake, as above cited. Of the overwhelming of *Bura* and *Helice* in the *Corinthian* gulph *Pliny* makes mention^t, as also *Seneca*^r after *Calisthenes*. Concerning the deluging the island *Atalanta*, see also *Seneca* from the account of *Thucydides*^u. And *Plato’s Timæus*, and *Kircher*^w of the *Atlantis* overwhelmed in like manner by an earthquake. They were such phænomena’s as these, that possess’d *Democritus* and the ancient poets with the notion, that the subterranean waters were the original cause of earthquakes, and made them give *Neptune* the appellation of ἐννοσίγαιον καὶ σεισίχθονα, the mover and shaker of the earth, according to *A. Gellius*^x.

Phæn. IX. Winds and flatus’s have also been observed to forego or accompany ruptures of the earth.

In earthquakes, says lord *Verulam*^y, “A cer-

^o Lib. citat. 4. ^p Ἡδὴ καὶ ὕδαλα ἀνερράγῃ γιγνομένων σεισμῶν. *Meteor.* ii. t. 48. ^q οἱ δὲ πηγὰς φαίνουσι πρότερον ἐκζεσας. ^r *Tom.* i. pag. 77. *tom.* ii. pag. 257. ^t Lib. i. cap. 92. ^u Cap. 23. ^v Cap. 24. ^w Lib. ii. *Mund. subterr.* cap. 12. ^x *Noct. Attic.* lib. ii. cap. 28. ^y *Hist. of winds.*

“tain unusual and unwholesome wind has been
 “observed before the eruption, as a sweltering
 “smoak breaks out before, and remains after
 “great fires.” And *Seneca* says^z, “that often-
 “times, when earthquakes are attended with any
 “opening, wind will issue for many days, which
 “thing is said to have happened in the earthquake
 “of *Chalcis*, as may be seen in *Asclepiodorus*, who
 “studied natural philosophy under *Possidonius*:
 “And other writers will inform you, that when
 “an aperture has been made in the earth, wind
 “has issued out of it soon after, or, in other words,
 “it escaped by a passage which it procured itself.”

Of this examples have been given above, and
Seneca himself says^a, “that there was something
 “of a venomous nature in the blasts which ac-
 “companied the earthquake in *Campania*, (which
 “was the occasion of his writing his sixth book
 “of *Natural Questions*) whereby a flock of 600
 “sheep was destroyed in the *Pompeiana Regio*.”

Phæn. X. On the other hand rivers, fountains
 and lakes have vanished away from the places they
 formerly possess'd; seas have deserted their wonted
 shores, at least for a season; and new islands have
 emerged where the waters usually flowed without
 interruption. I call *Seneca* for a witness^b, who
 asserts that in his own days the island of *Therasia*
 arose out of the *Ægean* sea, in the sight of several
 mariners^c. To which may not improperly be
 referred the origin of *Sicily* on the *Italian*, *Eubœa*

^z Lib. vi. cap. 17.

^b Lib. citat. cap. 4.

^a Cap. 1.

^c Cap. 21.

on the *Bæotian*, and *Cyprus* on the *Syrian* coast, of which *Pliny*^d, after he had proved the present position in a preceding chapter. Of the disappearing of rivers and lakes in modern times, we have already mention'd a notable instance in *Peru*, from *Gassendus* and *Furnerius*: And there is a signal and a recent example of new islands, formed about the beginning of *July* 1686, as may be seen in *Gassendus*^e. Thus the volcano of *Sicily* has produced a kind of offspring, or new little mountain, thence called *Volcanello*, as we learn from *Kircher*^f. And the same historians relate that the ocean receded and returned with a great swell soon again, before the often mentioned earthquake in *Peru*; and further, that the same thing happened in the port of *Naples* before the raging of *Vesuvius* in 1631; insomuch that *Hieronymus Welschius*, a spectator of this uncommon scene, says, “ that
 “ several ships were in great danger of perishing,
 “ by being suddenly let down on land by the
 “ retreat of the sea^g.

Pben. XI. Sometimes the duration of earthquakes is exceeding short, consisting of no more than a few pulses. Some again have lasted whole days, and even months and years, by fits. “ If
 “ they are not soon over, says *Pliny*^h, they may
 “ probably last 40 days, and even longer, for
 “ some have not wholly ceas'd in less than one,
 “ and sometimes two years; and this he repeats

^d Lib. ii. cap. 88.

^g Itiner. p. 81.

^e In x. Laert. p. 1051.

^h Lib. ii. cap. 82.

^f Loco citat.

“ in another place ⁱ.” *Aristotle* speaking of the more violent sort ^k, maintains, with *Pliny*, that they do endure about that space ^l. Notwithstanding, this is what rarely happens; and although the earthquake of *Campania*, whereof he writes ^m, did indeed continue several days, yet it does not appear to have held out altogether so long, nor did that other which overspread *Sicily* in 1537, exceed 11 days; and lastly, that which *Gassendus* observed at *Aix* in 1617, the night following the 13th of *January*, was quite over in less than three quarters of a minute.

Phæn. XII. They do not attack one single place, but for the most part extend themselves to several cities and countries very distant from one another, tho’ they exert various degrees of violence at the very same time; and this was abundantly confirmed in our late instance. For all accounts agree that it was first felt at the very same instant of time, at *Lindau*, *Kempton*, and many other places, as at the cities and towns abovementioned; but in how different a manner it display’d itself according to their several distances from *Hall*, where the scene was most dreadful, may be collected from the beginning of this discourse. The same was observable in that of *Campania*, which *Seneca* describes ⁿ. “ *Pompeij*, “ a considerable city of *Campania*, says he, was “ thrown down by an earthquake, and the shock

ⁱ Lib. ii. meteor. ^k ἔταν δισχυρὸς γένηαι σεισμὸς, &c. text. 45. ^l μέχρι περὶ τεσσαράκοντα ἡμερῶν. ^m Cap.

30. ⁿ Lib. vi. quæst. nat. cap. 1.

“ was perceived at the same time through all
 “ the adjacent country : And a little after part
 “ of the town of *Herculaneum* fell, and what con-
 “ tinued standing, remains in a tottering condi-
 “ tion; and notwithstanding none of the inhabi-
 “ tants of *Nuceria* lost their lives, yet their mis-
 “ fortunes were to be pitied : *Naples* had but a
 “ small share in the disaster, and the villages ele-
 “ vated on the adjacent hills, were sensible of the
 “ stroke, without any damage at all.” In ano-
 “ ther place ° he says, “ when *Chalcis* was shaken,
 “ *Thebes* continued unmoved; *Ægium* reel’d two
 “ and fro, at the same time that *Patrae*, its near
 “ neighbour, felt not the least motion, &c.” and
 concludes, “ that such motion never is extended
 “ to the distance of 200 miles.” Which if it always
 held true in those days, it no longer does so now:
 For *Gassendus* takes notice, in the place above ci-
 ted, that “ not far from *Lima* (which, if I rightly
 “ remember, had then lately suffered an almost to-
 “ tal subversion) there happened an earthquake
 “ which ran 300 leagues along the coast, and
 “ more than 70 into the continent,” to which
 add some other particulars which will be found
 under *Obs.* I. cited from *Meterranus* and *Kircher*.

Phæn. XIII. Mountainous places near the sea
 are chiefly expos’d to the most violent earthquakes;
 whilst flat, marshy, inland countries, seldom or
 never feel any shocks, at least no original ones.
 The ancients, as *Aristotle*, *Pliny*, &c. looked upon
Ægypt, *Gaul*, the isle of *Delos*, &c. as quite ex-
 empt from such visitations: Yet *Seneca* ^p asserts

° Cap. 25.

^p Cap. 26.

on the contrary, and experience proves earthquakes happened in all these places, tho' seldom, and in a milder degree. At *Alexandria* near the *Nile* in *Ægypt*, for example, about the year 551, and near *Bourdeaux* in *France*, in 584, according to *Garcaeus*^a. Nay we read in *Kircher*^r that in the year 1660 in the month of *June*, an earthquake was propagated from this last city as far as *Narbonne*. What we have advanced concerning maritime and mountainous places, is confirmed by *Aristotle* in several examples^f to which *Pliny* assents^t, remarking, that "though sea coasts are
 " obnoxious to the severest shocks, yet are not
 " mountainous situations altogether free from
 " them;" which he proves from the *Apennine* mountain and the *Alps*, which latter were not long since the theatre of such like devastation. And *Seneca* alledges *Pompei* and *Herculaneum*, *Paphos* and *Cyprus*, *Tyre* and *Sidon*, as other examples^u. *Peru*, *Campania*, *Calabria*, *Sicily*, &c. have been mentioned above as maritime countries, and abounding in mountains. As to marshes, muddy and sandy countries, as *Egypt* and *Tuscany*, *Kircher* may be consulted^w. And the country about *Nuremberg* may testify for itself. As for *Garcaeus* his observation, that the more southern parts of the world are less obnoxious to earthquakes, than the northern, he is much in the wrong, as may

^a Meteor. p. 389 and 405.

^r Mund. subterr. 257.

^f Lib. ii. meteor. t. 42. περὶ τέρας τοιόυτας οἱ ἰσχυρότατοι γίγνεται τῶν σεισμών, ὅπερ ἡ θάλασσα ῥωδῆς, ἢ ἡ χώρα σαρμῶν καὶ ὑπανίεσσι.

^t Lib. ii. cap. 80.

^u Cap. 26.

^w Mund. subterr. tom. i. p. 222.

appear not only from several of the foregoing remarks, especially in *Phæn.* VII. but even from his own catalogue ^x.

Phæn. XIV. It is furthermore certain that earthquakes have happen'd at all seasons of the year, by night and by day, and under all varieties of constellations, indifferently. *Aristotle* ^y, and *Pliny* ^z, who in this matter almost copies him, are of opinion that most of them fall out in spring and autumn, oftner in the night than in the day-time, especially a little before day-break. Our example, it must be allowed, confirms the latter, but then it seems to contradict the former; it attacking us in *July* in the very heat of summer, in the morning twilight, one hour after the change of the moon, no other remarkable aspect offering at that time, except an approaching conjunction of *Jupiter* and the Sun, which the astrologers reckon no malevolent one. *Kircher* has these notable passages on this subject ^a. “As for what
“*Aristotle* advances as to the time of earthquakes
“happening, of islands in the middle of the sea
“being at all times without them, and their last-
“ing 400 days, as it is contradictory to experi-
“ence, we must not altogether rely upon it: For
“they are not only places near the sea, and is-
“lands just disjoin'd from the continent, that are
“visited by earthquakes; but they happen in the
“very heart of large inland countries, and at all
“seasons of the year; a thing so well settled from

^x Meteor. p. 393 & seqq.

^y Lib. ii. meteor. t. 41.

^z Lib. ii. cap. 80.

^a Tom. i. lib. iv. Mund. subterr. sub finem cap. 10. sect. 1.

“ observation and experience, that it admits of
 “ no manner of doubt.” *Seneca*’s words are very
 exprefs, “ that the city of *Pompei* fell by an
 “ earthquake in the winter, (to wit on the nones
 “ of *February*) tho’ our fore-fathers pronounced
 “ that feafon to be void of any fuch danger^b.”
Tacitus affures us that the earthquake which threw
 down the twelve cities of *Asia*, came in the night;
 on the contrary that which *Kircher* himfelf faw,
 was in the day-time. That at *Lima* in *Peru* was in
 the winter on the 24th of *November*, five days after
 the new moon, *Mars* and the moon being in con-
 junction, but the moon at the fame time in quar-
 tile to *Mars*, and in fextile to *Mercury*. Now let
 any one who has leifure, confider well the feveral
 examples adduced above; after which let him
 carefully perufe *Garcaus*’s catalogue of earth-
 quakes, each accompanied with its concomitant
 configuration of the heavens from *Ephimerides*;
 and I am fatisfy’d he will be convinc’d, that there
 is no feafon of the year, nor any celestial configu-
 ration under which an earthquake may not hap-
 pen, as well as at any other time.

Phæn. XV. After a very fevere earthquake has
 happened, attended with a great conflagration,
 fuch another does not fucceed in a fhort fpace of
 time, but for the generality after a long interval,
 and then efpecially when a neighbouring volcano
 that was almoft extinct, flames out afrefh, or affords
 tokens of doing fo foon. *Seneca*^c proves the truth
 of this obfervation, and *Campania* and *Sicily*, *Ætna*
 and *Vefuvius* are vouchers, as well as feveral other

^b Cap. 1.

^c Lib. citat. cap. 31.

places mentioned in *Phæn.* VII. See likewise the writers there cited. It is remarkable, by the bye, that several volcano's which formerly threw out fire, are now utterly extinguished. The island of *Querimodam* on the *Brasil* shore, not far from the river *Plata*, for example, as also certain mountains in *Congo* and *Angola*. Geographers reckon several places among the *Azores*, especially in *Ter-cera* and *St. Michael*, which formerly flamed out, but of latter days have emitted nothing but smoak, which also has ceased in some of them; whence we may infer that some parts of the earth may in time get rid of such accidents; *Aristotle*^d, I know, thinks the thing impossible, but I can perceive no reason why he should do so.

Phæn. XVI. It is said that fiery meteors have been the forerunners, and sometimes the concomitants of earthquakes: Also a continually clouded sun, a turbid foulness of wells and fountains, infected with a filthy saline taste, a desertion of animals and birds, &c. and that to these have succeeded, pestilences, contagious diseases, famine, sedition, and a train of other evils: Of which *Pliny*^e, *Aristotle*^f, *Seneca*^g, *Garceus*^h, and others. Notwithstanding which it would be well worth our inquiry, to examine well if these things have really at all times or for the most part, any natural connexion one with another, or that it was by mere accident that they preceded or followed after. I shall set down some modern instances.

^d Lib. meteor. t. 4c.
ii, meteor t. 42, 43.

^e Lib. ii, cap. 81.

^f Lib.

^g Loc. cit. ^h In catal. terræmot.

When *Vesuvius* raged in 1631, *Welschius*ⁱ, who was present, observed that the sun was darkened, and a general duskiness was diffus'd through the whole atmosphere, from the very copious eructation of ashes; so that it seemed to look as if lightnings were glanced from a cloud which covered the head of the mountain; and it was confirm'd by abundance of letters from *Italy*, that the same scene was repeated again, tho' with a much more horrid appearance, in the month of *July* 1660. Thus the mountain in the island of *Java*, which in the year 1586 was riven asunder by a violent eruption of burning sulphur, sent forth such a vast quantity of thick black smoak for three days together, mixt with flame and fiery sparks, as obliterated the sun, and almost turned the day into night^k; and the like was observed on another mountain called *Gonnapi*. To which may be here added the relation sent from *Ternate* to *Bandam*, of the rending of mount *Gammacnorra*, as before recited in *Phæn.* V. So also in those most horrible earthquakes which afflicted the inhabitants of *Santorini* in the *Archipelago* in 1650, from the 24th of *September* to the 9th of *October*, the sky was darkened, and the air infected with stinking sulphureous vapours, to such a degree, as blinded every body that ventur'd out of doors, for three days together^l.

ⁱ Itiner. p. 80.

^k *Varen.* lib. x. cap. 10. prop. 5.

^l Test. P. *Francisc. Riccardo*, in mund. subt. *Kircher.* p. 182.

HYPOTHESIS

Framed for solving the foregoing PHÆNOMENA.

I. I Shall say nothing of *Bodinus's* dream of evil genij, mention'd by *Honoratus Faber*^m, nor of the *Japoneſe* dragon ſo largely treated of in the embaffy to that iſland, nor of *Tbales's* conceit of the earth floating in water as a ſhip on the ocean, and of the toſſings ſhe now and then undergoes. But I muſt obſerve that *Democritus* of old, and ſome others, whoſe doctrine as to this matter were not much oppoſed by *Epicurus*, and in a manner aſſented to by *Seneca*ⁿ, held that there are mighty rivers continually running, and vaſt oceans in a perpetual agitation below in the ſubterranean regions, and that, when any colluſtation happens there, the earth of conſequence muſt tremble and ſhake; and that the ancient poets had this notion, is evident from *Aulus Gellius*^o. *Anaximenes* affirm'd that “ the earth was the cauſe of its own
“ motions, by letting ſome of its parts drop into
“ its cavities, which were either diſſolv'd by wa-
“ ter or prey'd upon by fire, or driven about by
“ winds, or deſtroyed by time^p.” Others maintained, with *Archilaus*, that winds inſinuating themſelves into the bowels of the earth, do there impel the compr'eſſed air, and force it to break through its confinement.

^m Tract. vi. prop. 22.

ⁿ Lib. vi. nat. quæſt. cap. 7, 8.

^o Lib. ii. cap. 28.

^p *Senec.* cap. x. c. 1.

II. A like opinion prevail'd in the *Peripatetic* school for several centuries. And *Seneca* himself did not deny the ingress of winds from without, although he ascribed these calamitous accidents rather to subterraneous exhalations and vapours^q. For the notion ran, that there was a constant evaporation from the earth, sometimes dry and sometimes combined with moisture. When this was sent up from below, and raised as far as it could go, and meeting with an obstruction, was forced back upon itself, then conflicts and tumultuous motions arose. To this point likewise tended *Aristotle's* hypothesis, as appears plainly in his *meteorologies*^r. For he sets out with asserting, that both moist and dry exhalations are raised within and about the earth, and when these are over copious they produce earthquakes. For the earth being saturated with moisture, and heated by the sun without, and by fire within, πολὺ μὲν ἔξω πολὺ δ' ἐντὸς γίνεσθαι τὸ πνεῦμα. Καὶ τῷτο ὅτε μὲν συνεχὲς ἔξω ῥεῖν πᾶν. ὁ τὲ δὲ εἰς πᾶν. ἐνίοτε μερίζεσθαι. That is, *much spirit is generated without, and much within. Sometimes this is discharged entirely outwards, sometimes it is absorbed inwards, and sometimes it is divided.* Which, as he seems to have advanc'd for want of something better, he endeavours to puzzle the cause. Now, we are to consider, says he, ἐποῖον κινήσιμον αὐτὸν εἶναι τῶν σωμάτων; *what is that body of all others that is most strongly dispos'd to motion?* Why doubtless, he answers, τὸ σφοδρότατον, *that which is most violent,* and such he concludes to be τὸ τάχιστα φερόμενον, *that which moves swift-*

^q Cap. 13 and 23.^r Lib. vii. cap. 8.

est, and *τολεπρότατον*, the most subtle and penetrating: ὥστε εἴπερ ἡ τῆς πνεύματος φύσις τοιαύτη, μάλιστα τῶν σωματίων: Since then this is the most aptest of all bodies to motion. From whence he deduces this final conclusion, ἐκ ἂν ἐν ὕδαρ, ἐδὲ γῇ αἴτιον εἶη, ἀλλὰ πνεῦμα, τῆς κινήσεως, ὅταν ἔσω τύχη ῥυέν τὸ ἔξω ἀναθυμιάμενον. Wherefore neither water nor earth can be the cause of (its own) motion, but spirit, (or vapour) when, by any accident, the external exhalation is turned inwards.

III. The greatest defect of *Aristotle's* hypothesis, is that he unluckily never thought of an actual accension, or kindling of the dry exhalations excited within the earth, which the inflammation of gunpowder might have hinted to him, had he been acquainted with it: Yet he could not but have been well informed of the burning of *Ætna* and *Lipara*; and he most certainly was so, if the book *περὶ θαυμασίων ἀκυσμάτων* be his, which might have supplied him with the like notions as those which occur in the book *de Mundo*^f; unless, with *Heinsius*, we deny that *Aristotle* was the author of that treatise too, in which earthquakes are derived from subterraneous fountains of fire, much in the same manner as that whereby the modern philosophers have endeavoured to account for them. Indeed the ancients according to *Seneca*^g, had. *Anaxoras* referred the cause of earthquakes to subterraneous clouds bursting out into lightnings which shook the vaults which confined them. Others, that the arches which had been weakened by continual fires, at length fell in, others de-

^f Cap. 4.^g Cap. 9.

riv'd these accidents from the rarefied stream of waters heated by some neighbouring fires: and some, as *Epicurus* of old, (among the rest of the opinions collected by *Seneca*^u) and, as *Andreas Cæsalpinus*^w shews, several of the Peripatetic school also ascribed these horrible accidents to the ignition of certain inflammable exhalations.

IV. And this has been the favourite hypothesis of the most celebrated modern philosophers, *Gassendus*, *Kircher*, *Schottus*, *Varenius*, *Des Cartes*, *Du Hamel*, *Honoratus Faber*, &c. Though it should be noted, that this last imagines that waters extremely rarefied by heat, may sometimes force a way through their proper boundaries, and that included vapours may, under the like circumstances act in the same manner, and so be sometimes also productive of earthquakes. These learned men do suppose that there are many vast cavities under ground which have a communication with one another by intermediate canals, some of which abound with waters, others with vapours and exhalations arising from inflammable substances, as bitumen, nitre, sulphur, &c. and also metals and minerals, congested together, at all times disposed for inflammation, and on some occasions in an actual state of accension: All which doctrine is consonant both to reason and experience, as will be presently proved at large. Now whether such combustible exhalations as these happen to be kindled up by any subterraneous spark, or from some active flame gliding thro' a narrow fissure from without, or in consequence of the fer-

^u Cap. 20.

^w Lib. iii. quæst. peripatet. 9.

mentation of some mixture, they must necessarily produce pulses, tremors, or ruptures at the surface, according to the number and diversity of the cavities, and the quantity and activity, &c. of the inflammable matter: *Honoratus Faber* illustrates this doctrine by a variety of artificial earthquakes, as he calls them, confining gunpowder, (a mixture of nitre, sulphur and charcoal) in pits, and setting fire to it by a train ^x.

The last mentioned hypothesis I acknowledge for my favorite; being such as the nature of burning mountains, as well as of those parts of the earth, most liable to earthquakes do plainly indicate; for they all abound in sulphur, nitre, bitumen, and the like inflammable substances. This, of all the rest, has the advantage of satisfactorily accounting for the several recited phænomena; to evince which I shall premise a few observations, as principles of future conclusions.

I. The earth incloses great numbers of spacious cavities, vaults and canals, especially under the summits of mountains. To pass by the famous *Specus Coricianus* spoken of by *Mela*, *Solinus*, *Pliny*, *Strabo*, &c. *Pluto's Den*, mentioned by *Ælian*, and other subterraneous hollows scattered up and down in *Seneca*, the amazingly extended caverns under the *Andes* in *America*, and those in some parts of *China*, described by *Martinius* ^y, and more at large by *Kircher* ^z, I prove my assertion from those strange spiracles, called, from the continual blasts

^x Lib. citat. Prop. xxx. Vide etiam Gassend. Physic. Sect. III. Memb. I. Lib. I. Cap. 6. p. 48, 49. ^y In

Ablante Sinic. ^z Mund. Subterr. Lib. II. sub finem.

they send forth, the *Æolian Bellows*, which the same *Kircher*^a both describes and saw; I prove it from the innumerable sources and waters every where abounding; and lastly, I prove it from the vulcano's and burning mountains distributed through many regions of the world, as *Italy, Asia, Media, Tartary, Japan, the Philippines*, and other parts of *India, Africa, Terra Australis, Mare del Zur, the Canaries, North and South America, Greenland, Island, &c.* of which according to authors of the best credit cited in *Phæn. VII.* there is an immense number: And one thing is to be particularly remarked, that the cavities of these burning mountains do not terminate at their bases, but are far extended in canals which often communicate with one another. When mount *Ætna* of old begun to emit flames, *Strongylus* in the *Liparæ* Islands did the like at the same time, the sulphureous steams diffused under all *Sicily* taking fire at once: And altogether as remarkable, or more so, is *Kircher's* observation, concerning that most terrible earthquake in *Calabria*, which himself saw and felt, that *Strombulo*, 60 *Italian* miles distant, was not only heard to bellow and seen to blaze a little before, but that the subterraneous noise was first distinguished but dully, and then waxed louder and louder, till it arrived under the spot on which he and his companions stood.

Observ. II. Some of these caverns and subterraneous passages, when replete with water, form gulphs, abysses and rivers, and some give rise to springs; others are occupied by flatulences and exha-

^a Loc. cit.

lations ; and others again with fire and flames, as hinted in the proofs of the foregoing observation. But for further confirmation, of what relates to waters, it will demand but a moderate degree of sagacity to conceive what vast reservoirs of that fluid lie under the *Alps* for example, which pour forth so many great rivers, as the *Danube*, the *Rhine*, the *Inne*, the *Rhone*, the *Saone*, the *Maese*, the *Moselle*, the *Po*, the *Etsch*, the *Mencio*, the *Tesino*, the *Save*, the *Drave*, &c. besides the great lakes of *Swisserland*, as the *Lucern*, the *Lemann*, that of *Zurich*, and the lesser ones as you enter *Italy*. The concavities under *Taurus*, *Antitaurus*, *Caucasus*, and *Imaus* in *Asia* ; whence flow the *Indus*, *Ganges*, *Oxus*, *Hydaspes*, and several rivers of *China* ; likewise the *Euphrates*, *Tigris*, &c. The like under the *Mountains of the Moon* in *Africa* ; whence the *Nile*, the most celebrated of all rivers ; the lakes *Zaire*, *Zembre*, &c.—Under the *Andes* in *America*, which pour out a profusion of mighty rivers and lakes on every side, herein exceeding all others. Whence it is easy to imagine what an infinity of other lesser receptacles of water there must exist throughout this globe, whence rivers of lesser note are derived ; and, if the earth be properly called the *Terraqueous Globe*, ought it not to be so ? As to the second part, which concerns flatuluses and exhalations, peruse what *Gaspar Schottus*, a disciple of *Kircher*, writes about artificial winds generated *intra Æolias Cameras*, by the fall of water^b, and then judge what quantity of winds must of necessity be continually excited in the bowels of the earth

^b *Magia Musica*. Syntag. IV. cap. 10.

from the boisterous dashing of the ocean against the shores, and the ingress of its waves into the subterraneous caverns. As to the third part, fire, consider, 1. what a vast plenty of hot springs is there in all parts of *Germany*, *France*, and *Spain*. Can these receive their heat, as it were by accident, merely from the abysses of volcano's prolonged through an innumerable variety of canals, or must not they owe it to a more extensive infernal fire? 2. *Æstuaries* and eruptions of fire are to be seen at *Petra mala*, and about *Puzzoli* in *Italy*, and in many other places, and sometimes they have been known to be thrown up from the bottom of the sea, as in 1650, and long before in 1457 and 1570, near the island of *Santorini* in the *Archipelago*. 3. It should be observed, that all these things are agreeable to the oeconomy of nature. The whole stock of waters under the surface of the earth would be converted into ice, if some of them were not exceedingly heated by the proximity of subterraneous fire. Again, These very fires would be extinguished, were it not for the recreating blasts of air, produced by the ocean as before hinted, or admitted in through the apertures of volcano's. And finally, there would be a total consumption of all, from the same fires, were they not restrained and partly extinguished, by the intervention of waters and humid vapours. I might here recite a notable passage to this purpose out of the book *de Mundo*^c, and another from *Andreas Cæsalpinus*^d, had I not so long insisted in the proof of this 2d observation.

^c Cap. 4.^d Lib. III. Perip. Quæst. IX. p. 77.

Observ.

Observ. III. The bowels of the earth do every where, but chiefly in mountainous places, hold more or less of sulphur, bitumen, nitre and other salts, amber of various kinds, &c. also divers metals, and that in great plenty; but these substances are observed to abound most of all in countries which have been visited with the severest earthquakes. Natural geography and experience teach us, that all *Sicily*, *Campania*, *Tuscany*, and indeed *Italy* in general, have plenty of sulphur, bitumen, coals, pumice stones, iron, copper, and other ores, and the like holds good of many others. Where-soever burning mountains are found, and we have seen above that few parts are without them, there these inflammable minerals are even belched forth: And it is very remarkable that the Isle of *Ormuz* in the *Persian* Gulph, which geographers report to be in a manner all salt, did not only burn seven whole years together, but does even to this time daily throw forth balls of flame from its saline mountains, a certain token of the truth of that observation among naturalists, that fossile salt is rarely found pure, and void of all metalline mixture, or a degree of unctuous fatness. Nor need I mention that *Pliny* and *Albertus Magnus* affirm, that oil may be extracted from salt, and salt from all metals and earths; or alledge a curious and a decisive experiment to prove that the earth every where abounds with fatness and the *pabulum* of flame*. It were needless here to say any thing of the mines and minerals of *Germany* and its neighbouring countries, of which the geographic writers

* Vide Kircher, Mund, subterranean, Tom. I. p. 185.

are so full. I must however take notice, that in *Misnia* there is a mountain of coals, which frequently sends forth smoke, and sometimes actual fire, whose flames about the year 1505, *Agricola* the great mineralist saw raging to an excessive height. And *Bernb. Cæsius* writes ^f, that frequently in the night season flames break out and blaze through the whole tract of land between *Zwiccaw* and *Glauch*. Which writer gives a very large account of the several countries of the world that principally abound in sulphur, bitumen, salt, succinum, and other minerals and metals. This one thing more I have to add, that from the fiery eruptions at *Santorini*, spoken of above, it is manifest that even submarine places are not entirely destitute of sulphureous and bituminous minerals: And that the frequent appearance of fiery meteors, in every part of the known world, afford a general argument for the existence of such inflammable substances every where under ground; for all naturalists allow that they can be no other than ignitions of such exhalations.

Observ. IV. It stands therefore with reason as well as experience, that the subterraneous cavities and passages are full of exhalations continually and copiously raised from these inflammable bodies, and that such steams are no less inflammable than the bodies themselves which they are produced from, whether they happen to be kindled by some fortuitous subterranean spark, or from the fermentation of the steams of different bodies: For as they are

^f Lib. I. de Minera. cap. 7.

elevated as high as the middle region of the air, where they can meet with no fire to ignite them; what is more probable than that this operation is performed in the under regions of the earth? Moreover, that vast quantities of the exhalations of such bodies are congested in the bowels of the earth is evident from this alone, that sulphur can never be dug deep under ground, but only from mines exposed to the open air and day-light, otherwise the miners would be suffocated thereby; and on the same account all places in the neighbourhood of the *Asphaltites* lake are absolutely uninhabitable. That an ordinary candle is capable of setting such steams in a blaze, is obvious in *Naptha*, a few drops of which as soon as poured out, will spread also a pinguous vapour through whole streets, producing an inflammation in the air wherever it reaches. And lastly, that ignition may arise out of mere fermentations, without the presence of any actual flame, is proved from the easily kindling up of a mixture of nitre, sulphur and quick lime, by moistning it with a little water or spittle^g. It is further very remarkable, that not only several of these inflammable substances either by themselves or mixed with others, will burn in the midst of water; but that even gold, and other metals, minerals, &c. duly prepared, will be easily put in a state of accension not only by fire, but by a moderate degree of warmth alone, and thereby produce amazing effects; such as I have myself

^g Vide *Gasp. Schott. mag. pyrotechn.* p. 121.

more than once beheld, and of which the afore-cited author treats at large^h.

Obf. V. The force of fuch inflammable vapours, to produce motion, and alfo pulsations and shocks, when in a state of actual accension, is prodigious. “ The power of gunpowder fired in ordnance or in
“ mines, is well known: That it is capable of over-
“ setting and blowing up the most solid founda-
“ tions. And if we examine into the cause of so
“ vast an impulsive force, we shall find it to reside
“ in nothing but a composition of a little nitre,
“ sulphur and charcoal. But if there be so much
“ strength in a small quantity of this artificial
“ powder, how immensely greater may we not
“ suppose that to be, which arises out of nature’s
“ treasure of combustible materials of sulphur,
“ nitre, alum, sal ammoniac, bitumen, and other
“ spirits of minerals, metals, gold, copper, iron,
“ arsenic, quicksilver, &c. every one plentifully
“ stored up in the hidden cavities of the earth?”
I use the learned *Kircher*’s words, as the aptest to express my meaning. Travellers who have visited *Vulcan*’s fields near *Puzzoli*, give a horrible description of the impetuous blasts which some of those spiracles belch out, with most astonishing noises, and with a force able to repel back into the air large stones thrown into them. What a huge crack do the fulminating powders of gold, copper, tartar, &c. produce in their explosion; violently bursting to pieces whatsoever obstacles they meet with? To say nothing of the dreadful and

^h *Mechan. Hydraulic* p. 63. vide etiam *Gassend. animadv.* in *Diog. Laert.* p. 1016, &c.

penetrating energy of lightning; which the city of *Stralsund* in *Pomerania* not long ago sadly experienced.

Observ. VI. The force of spirituous bodies in a state of rarefaction, even without accension, is also very great: However, without the concurrence of some extrinſick impulse, it ſeldom manifests itſelf in ſudden ſhocks and concuſſions; but chiefly in ſlighter tremors, ſometimes accompanied with ſimple ruptures of the ground. *Schottus* procur'd a ſort of little glaſs ſpheres to be made at *Rome*, and above forty years ago I diſtributed ſeveral of them among my friends at *Jena*, which I brought from *Amſterdam*. Theſe would give a report almoſt as loud as a muſquet. They were filled half full of vinegar or ſome ſpirit, and then hermetically ſealed. Being placed on burning coals or in hot embers, the liquor within, tho' rarefied by the heat, did not boil, or ſo much as move the ſphere, but, burſting its priſon at once, bounced as loud as a piſtol. Much in the ſame manner it comes to paſs that pillars of marble which the united force of an hundred yoke of oxen cannot pull aſunder, are by authors of good credit affirmed to be eaſily broken to pieces by the rarefaction of a little air or ſpirituous fluid lodged in their pores, when ſurrounded with fire; but at the ſame time they make not the leaſt mention of any tremors or reiterated pulſations preceding the diſruption.

Observ. VII. Metals and minerals are not only formed in the bowels of the earth, but after having

ing been removed, are again regenerated in the very same places. This is obvious to every day's experience, as may be proved from *Agricola*ⁱ and *Cæsius*^k; especially in the island of *Ilva* or *Elva* in the *Tyrrhene* sea, where it has been observed that a mine entirely cleared of its iron ore, had it renewed in the space of twenty five years: And lead gutters exposed long to the open air on the tops of houses, have been found to exceed considerably their original weight; also metalline shafts or adits wrought at first large enough to admit an easy passage to the miners, have in process of time grown so narrow, as to be quite useless, which could no otherwise come to pass, but by an accession of new matter, according to the sentiments of the now mentioned writers.

Observ. VIII. Mineral steams are indeed sometimes found to be harmless, especially when temper'd with an intermixture of bodies of a different nature: Yet for the most part they are observed to be noxious, especially if over copious, both to men and beasts. The former part of the observation is proved by the salubrity of hot springs and medicated waters, plentifully impregnated with steams of sulphur, nitre, &c. Such are frequently met with in *Italy*; nor are they very scarce in *Germany* and other countries about it. The latter part is notorious from the number of diseases which arise from metals and metalline fumes; some attacking the joints, others the lungs, some the eyes, and others again the whole habit, so as

ⁱ Lib. v. *de ortu caus. subterr. & conimbric.* tract. 13. met. cap. 2. ^k Lib. i. *de miner.* cap. v. sect. 5.

to bring on death. By repeated observation it has been found, that in pits and quarries where stones have been broken by fire, the air is vitiated with a poisonous infection, and the cracks and junctures of these stones do exhale a subtle virulent steam, which the fire forces out from interspersed metalline particles, of such a nature, that when any animal bodies are infected with it they swell, and lose all sense and motion. It is reported that near *Plana*, a town of *Bohemia*, there are grottos which at certain seasons of the year emit a vapour which extinguishes lights, and kills the miners who tarry a small time in it; and of the like nature is the soil about *Puzzoli*, and the famous *grotta di cani*, the lake *Avernus*, &c. several more of which are to be met with in the writings of *Bernard Cæsius*¹, *Athanasius Kircher*^m, and *Seneca*ⁿ.

Conclusion I. The earth being, (by *Observ. I.*) every where below hollowed out into caverns and canals, which (by *Obs. III.* and *IV.*) includes vast stores of various metals, minerals, and readily inflammable substances; it may easily come to pass, from the fire, likewise diffused through the whole bowels of the earth (*Obs. II.*) that some little spark may from a great distance, by a chink or small aperture, find its way into the said caverns, and so set fire to the sulphureous and nitrous steams, or that they may be kindled up by some sudden fermentation: In either case it is evident (from *Obs. V.*) that so sudden an inflammation and rare-

¹ Lib. i. de miner. cap. vi. sect. ii.

^m Mund. subterr.

tom. i. lib. v. sect. iii.

ⁿ Lib. iv. quæst. nat. cap. 18.

faction, must necessarily, according to the greater or lesser quantity of combustible matters, their substance, tenacity, degree of driness, the extent, figure and position of the caverns, &c. produce various pulsations and other violent effects; represented, tho' in miniature, by gunpowder fired off in artificial mines, by a long train or match. And indeed in these days the knowledge of gunpowder has hinted the true cause of earthquakes in general, and of the various phænomena of particular ones, and that in a fuller and more satisfactory manner, than the ancients, for want of such assistance, could any ways make out.

Concl. II. Nor is it strange that ignes fatui, and other fiery meteors should sometimes be seen without any subterraneous accension, or ensuing earthquake; since the intervention of a little moisture may easily stifle and extinguish such sudden inflammation; or supposing some subterraneous vapours to be actually kindled, their flames may find vent, and escape through superficial cranies; just as the blowing up of artificial mines is frequently defeated by a dampness of the powder, or by a wrong proportion of the ingredients, or by the mine being too spacious for the quantity of the powder; or lastly, if through the carelessness of the engineers, or the craft of the enemy, there be any apertures whereby the flame of the kindled powder can find a vent.

Concl. III. But when spirits in a state of actual inflammation are so confin'd as to have no passage at all to escape through, and at the same time the pressure of the incumbent mass, or the

cohesion of its parts be too great to yield to the impulse; the consequence then will be at least a commotion and tremulous concussion, in proportion to the said incumbent mass. And here, by the way, it may be observed, that since the caverns below the earth's surface, cannot in reason be supposed to bear any proportion to the whole globe; this alone may afford an easy solution of the second phænomenon.

Concl. IV. It is easily to be comprehended, that when the impulse is directed parallel to the horizon, or upwards perpendicular to the surface, or obliquely between both, it can force a passage through the obstacle no otherwise than from the various positions of the caverns and canals; that is, as they happen to point horizontally, vertically, or obliquely; just as in guns, the force of the powder is directed the same way that the piece is planted: And on this footing the diversities of general earthquakes mentioned at large in *Phæn.* III, IV, and V. will be satisfactorily accounted for.

Concl. V. Nor is it difficult to foresee, if it should so happen, as it very easily may, that a cavern transversely extended in length, should be ignited near its middle, so that the impetus must be directed at the same time to both its extremities, what would be the consequence; namely that those extremities receding farther asunder, must during the blast, produce a rupture in the roof above, which as soon as that was spent, would close again with a reciprocal force: And such is the cause of the *arietation* described in *Phæn.* IV.

Concl.

Concl. VI. It is likewise manifest, that when any part of the earth suffers some degree of a shock, or a considerable trembling, even though the superficial part be not ruptured asunder, such superincumbent lofty structures as towers, churches, &c. must be either thrown down or shattered thereby: As when a table receives a smart stroke on the under-side, drinking glasses placed thereon will be over-set; and nuts, fruit and the like, leap out of the plates that hold them. This shews how the *succussion* and *subversion* particularly described in *Phæn.* III and IV. are to be rationally explained.

Concl. VII. But when the earthen roof is too weak to resist the efforts of a more furious accension, the flames must needs burst open the gates of their confinement, and every thing upon the surface go pell mell to the bottom, the sides of the cavern at the same time collapsing; and thus whole cities, mountains, rivers and even islands, may be swallowed, and all those horrible effects produced, which were enumerated in the five first phænomena: Nor is the art of war practised under ground, incapable of working similar consequences.

Concl. VIII. And further, since it appears from *Obs.* II. that vast reservoirs and torrents of water are contained in the subterraneous apartments; what should hinder but that such a body of fluid may instantly overflow the cities, mountains, &c. newly swallowed up, and form large standing lakes, or flowing rivers, where there were no signs of them before? Which will satisfy the latter part
of

of *Phæn.* IV. and also the whole of *Phæn.* V and VIII.

Concl. IX. But if an huge bulk of earth be forced up obliquely through the incumbent sea, so as not to drop back into the submarine cavern, but to rest on the solid bottom near the aperture, with its top above the surface of the sea, a new island will be formed; and if at the same time much of the sea be absorbed into the abyss below, submarine hills may have their tops uncovered, and thus also become suddenly new islands: And thus the cause of *Phæn.* X. may be naturally explain'd.

Concl. X. And to the very same cause must the sea's instantaneous receding from the shore during an earthquake (as mentioned at the latter end of *Phæn.* X.) be ascribed; it being sucked into the new opened gulph below, and disappearing 'till distant waves flow in and supply its place.

Concl. XI. Nor is it to be accounted strange that when, and wheresoever earthquakes happen, flames should not at the same time be always visible: For these, if not extravagantly fierce and copious, may be smothered and extinguished by the fallen ruins of the earth, or by the overflowing of waters: Besides they may be often, either of so subtle a nature, or so involv'd in clouds of smoak, as in the day time to escape our sight, though they might be visible enough in the darkness of the night; of which *Ætna*, *Vesuvius*, and the fields of *Puzzoli*, do afford almost daily examples.

Concl. XII. Flames are a great deal more apt to burst forth from the tops of mountains, than in
I valleys

valleys or other low places, as being less check'd by the beforementioned obstacles, and likewise because the cavities under mountains are very frequent and large, and their sides by inclining together, form a kind of chimneys which favour their ascent. This explains the former part of the VIIth *Phæn.*

Concl. XIII. And since vast quantities of sulphur, bitumen, stones and metals, liquified by a most intense heat, are expelled from these infernal chambers through the tops of mountains, like stones and bullets out of artificial ordnance, they must be the pabulum whereby such fire is so long maintained, except that the crusty rubbish which drops off from the inward lining of those mountains, may sometimes supply it with new fuel. Hence the second part of *Phæn.* VII is deduc'd.

Concl. XIV. The cause is likewise manifest, why these ignivomous dragons, after having ceased for a while, through a total consumption of the combustible materials within them, do rage again: This being the consequence of another accension of newly generated steams and exhalations, which, like the former ones, forces a new vent for other ignited and melted substances, as in *Obs.* VII. and thus the last part of the same VIIth *Phæn.* may be, at least probably, accounted for.

Concl. XV. With the like ease may we conceive how ignited fumes and exhalations being rarefied in the bowels of the earth, do occasion tremors and shocks, as also winds and blasts, sometimes before the ragings of burning mountains, and sometimes after them; namely, in the former case,

case, because no vent is as yet opened; and in the latter, because it is closed up again before they have entirely escaped; and thus the force being distributed among the neighbouring parts, the inclosed air is driven out through whatsoever crannies it happens to meet with, as from æolipiles, and thus we have a very probable solution of the IXth *Phæn.*

Concl. XVI. Nor is it strange that such eruptions should be for the most part accompanied with horrible noises; we experience them in a proportionable degree upon discharging guns, exploding fulminating powders, and bursting bladders. And the variety of these noises, as bellowings, lowings, thunderings, roarings, &c. depend upon the different capacities and figures of the caverns and canals, like the various tones of an organ on the sizes and length of its pipes. Such is the cause of *Phæn. VI.*

Concl. XVII. Sometimes the chambers which contain the combustible matter are small and few, and their walls not so thin as to permit the kindled flame to make a sudden irruption into the contiguous ones, which rather burns a passage through by gradually consuming the intermixed sulphur and bitumen, and then perhaps meets with much more capacious caverns, through which being equally diffus'd, much of its primary force is abated, and its velocity retarded; which affords a satisfactory rationale of the different durations of earthquakes spoken of in *Phæn. XI.*

Concl. XVIII. And since it appears from *Kircher's* experiment cited at the latter end of *Obs. I.*

that the communication which subterraneous caverns have one with another, is frequently by long extended canals, what wonder is it that earthquakes are sometimes propagated to very great distances, in various directions? as we have observed in *Phæn.* XII.

Concl. XIX. But countries whose soil is sandy or loamy, are also frequently visited by tremors and shocks: Now it is extremely difficult to conceive, how, in such a contexture of earth, any caverns and canals of communication can possibly subsist. This however must be understood to take place by a kind of consent of parts, the impulse being begun at a great distance, and the jar propagated by contiguity of solid parts, as for example,

———*plaustris concussa tremescunt*

Teſta, viam propter, non magno pondere, tota:

Ferratos utrinque rotarum succutit orbes, &c.

as *Lucretius* elegantly describes it; and *Kircher* assents^o; which satisfies for the beginning of *Phæn.* XII.

Concl. XX. The causes why mountains and maritime places are most obnoxious to shocks and subversions, are, first, the redundancy of inflammable substances under mountains, according to *Obs.* III. and, secondly, the winds and blasts excited by the allision of waves, as being great promoters of accension, according to *Obs.* II. But in marshy and watery places, tho' much abounding in combustible matter under ground (such as

^o Lib. iv. mund. subterr. sect. ii. cap. 10. in fine.

Tuscany,

Tuscany, which *Kircher* gives for an example^P) and this actually set on fire, or just ready to be so, is easily quenched by the neighbouring moisture; so that earthquakes cannot be frequent here. And thus have we the cause of *Phæn.* XIII. with which compare *Concl.* II. At the same time we have the cause of the late disaster at *Hall*, a soil richly impregnated with salt; and the same inference may be made from what was said in *Obs.* III. about the isle of *Ormus*, and so we come at the cause of *Phæn.* I.

Concl. XXI. The inflammable substances we have all along been speaking of are not more liable to accension in spring or summer than in autumn and winter, nor more under one constellation than another, (*Phæn.* XIV.) It is not therefore strange that no times and seasons have been absolutely without the related effects. It is however not improbable that the winds blowing stronger, or the seas running higher at a certain season, may have some share in promoting them.

Concl. XXII. And as smoaky, nitrous and sulphureous steams, before their accension, or after it, may easily penetrate to the sources of springs; and as ashes and soot are frequently ejected in great quantities, without flame, through clefts and openings of mountains up into the air, the reason of *Phæn.* XVI. must be very obvious.

Concl. XXIII. Nor is it in the least strange, that mischievous and venomous exhalations (*Obs.* VIII.) should, by infecting the air, often bring on pestilential diseases, as was remarked at the end of the same *Phæn.*

^P Loco ante cit.

Concl. XXIV.

Concl. XXIV. But whether they portend seditions and other evils independent of truly natural causes, is not the business of the present enquiry. This it is manifest from experience, that *Ætna*, *Vesuvius*, &c. do render the circumjacent country extremely fertile by their eructation of a pinguious matter; and that *Greenland* and *Island*, otherwise intolerably cold, are cherished merely by these subterraneous fires, and rendered habitable; to say nothing of the profit that redounds to the inhabitants from the sale of the vast quantities of sulphur, wherewith they constantly supply them, affording them a very comfortable support, which otherwise they must be altogether in want of.

Concl. XXV. It cannot be questioned, but as the waves of the ocean do wear rocks, and wash away shores and the walls of cities; so may the waters have free power of washing, and excavating the inward parts of the earth in certain places, inso-much as to cause the vaulted roof above to drop in through its own weight; which particular is taken notice of by *Seneca*⁹, and has been confirmed by a late example in *Bulgaria*, where a tract of land six miles long, sunk down, without any earthquake, into a deep abyss; and not long since the gazettes mentioned a thing of the like kind of a mountain in *Russia*, where nothing of a subterraneous fire would have been suspected, had it not being accompanied with bellowings and roarings: and I wish I may be mistaken in my prognostic, as to the town of *Panama* near the isthmus of *Darien*, on the western coast of *America*, suffer-

⁹ Lib. vi. quæst. nat. cap. 7.

ing the like fate, especially if what is reported by some be true, that the waves of the sea are frequently heard to roar under the streets.

Concl. XXVI. But whether a tremor, properly so called, may be produced by a violent fall of waters into a subterraneous cavern, let the reader judge from what has been said above, compared with what *Athanasius Kircher* relates^r, that “*At Panama, a town of America, the flux of the sea is at some times so violent, that the place is full of water, and at the same time an earthquake is felt, and horrid bellowings are heard from under ground.*” And indeed although the hypothesis of *Democritus*, which may be met with at large in *Plutarch*, *Seneca* and *Aristotle*, that subterraneous waters are the cause of earthquakes, be insufficient to solve many of the phænomena, yet it must be acknowledged not to be in all respects absurd.

Concl. XXVII. Nor ought we to oppose *Aristotle*, and others of the ancients, as to the violence of flatufes, especially in a state of rarefaction (*Obs.* VI.) if they could but assign a cause either of instantaneous rarefaction, as that, for example, of air condensed in wind-guns, or of any violent impulse impress’d by continued flatus’s from a considerable distance; without which (by the same *Obs.* VI.) the varieties of earthquakes cannot be accounted for (nor indeed the other phænomena, especially the VIIth, if the origin of such impulse be supposed far distant) nor the artificial earthquake of *Arbmesius* described by *Agathius*^f, gain any credit.

^r Mund. subterr. tom. 1. p. 145.

^f Lib. v.

Concl. XXVIII. Wherefore as to these, and other opinions of the ancients, we must, in the general, agree with *Seneca*^t, that “*although they are rude and destitute of perfection, yet still ought we to excuse them; and think ourselves in some measure indebted to them for whatever improvements we may happen to make.*” As those who broke the ice, and first attempted such profound inquiries, in which they would beyond all doubt have succeeded, if artillery and gunpowder had been known in their times; for by this alone the moderns were led, and as it were forced into the discovery of the causes we have here assigned, of so intricate a matter; of which I will take upon me to produce unquestionable proof.

P O S T-

P O S T S C R I P T.

I. Intend in this additional paper to give due satisfaction to such as would choose to rely on the authorities of other men, rather than trust to their own judgment: And also to prove the truth of a proposition of the utmost importance in the whole science of nature. As to the former, I shall not, as I might, insist that many ancient philosophers deduced the causes of earthquakes, tho' not altogether satisfactorily, from the violent action of fire; and that among the several notions of *Epicurus* on the subject, this was his favorite one, "that earthquakes are produced by some
 " spiritual flatus converted into fire, which like
 " thunder, makes havock with whatsoever it meets
 " in its way," as *Seneca* reports^u; I rather choose to cite the authorities of a few of the most celebrated moderns.

II. *Caspar Schottus* in his explanation of the nature and action of mines in sieges, says^w, "The
 " military architects do hollow out a winding narrow passage, by the help of a magnetical compass, from the place where the siege is carried
 " on, to the very fortress they design to demolish;
 " and under it they work a vault, and close it up
 " with a door, which has a small hole bored at
 " its bottom; from which all along, as they retire, they lay a match or train, and set fire to

^u Lib. toties citat.^w *Mechan. hydraul.* p. 61.

“ it when they are got out: Thus the whole
 “ quantity of powder in the vault is kindled at
 “ once, and the rarefied flame enduring no con-
 “ finement, blows up the pile that stands over it,
 “ and in an instant spreads death and terror a-
 “ round.”—After which he adds the following re-
 markable words. “ Nothing was ever devised to
 “ exhibit so perfect a resemblance of an earth-
 “ quake, as that apparently is no other than an
 “ effect of rarefaction, and nature in producing
 “ those concussions, operates in a quite similar
 “ manner; for a flame from some subterranean
 “ furnace creeps along a vein of nitre or sulphur,
 “ till it arrives at a place where a much larger
 “ store of those materials are congested; which
 “ being suddenly kindled and rarefied, endea-
 “ vouring to expand itself into a larger space,
 “ shakes or oversets the incumbent mass.

III. How exactly the pupil and his master agree,
 may be seen in *Kircher's* writings ^x, where having
 advanced what we have cited about mines and ord-
 nance at the beginning of *Obs.* V. he immediately
 adds,—“ who can be ignorant that earthquakes
 “ have the like origin? They are brought about,
 “ as has before been shewn, in the bowels of
 “ the earth, and that in the following manner.
 “ When the powerful effort of subterraneous fire
 “ has broken through the sides of the caverns of
 “ mountains, and spread itself into a large space;
 “ the air there is put into a violent agitation, and
 “ the combustible particles with which it is copi-
 “ ously impregnated, being suddenly kindled, ex-

^x Mund. subterr. lib. iv. p. 221.

“halations are formed in vast quantities, and for
 “want of a vent for them to escape at, the utmost
 “colluctations ensue which nature is able to en-
 “dure; the hollow sides and vaults of mountains
 “are shaken, and the superficial parts of the
 “earth are lifted up, and, *mark the words*, these
 “elastic vapours work the very same effects, as
 “gunpowder in artificial mines: They burst
 “through every thing, overset cities and castles,
 “form horrid gulphs and new lakes, leaving be-
 “hind them the various monuments of desolation
 “and calamity, described in historians.”

IV. *Descartes* goes further^y. “The subtile
 “particles of exhalation, says he, being too much
 “agitated to be converted into oil, when acci-
 “dentally driven in any considerable quantity
 “through the crannies, and into the cavities of
 “the earth, do there constitute greasy thick fumes,
 “not unlike those which arise from a new extin-
 “guished candle; and then if any spark of fire
 “happens to be excited in those cavities, the
 “fumes are presently kindled up, and in conse-
 “quence of an instantaneous rarefaction, do shake
 “the walls of their prison with prodigious force,
 “especially if a great deal of spirit or *aura* be in-
 “termixed with them; and in this manner are
 “earthquakes produced.” See likewise his other
 opinions about the duration of vulcano’s and
 earthquakes, which I cannot but think highly
 probable.

V. But the learned *Gassendus* of all others, has
 the most ingeniously deduced the causes of earth-

^y Princip. part iv. Num. LXXV.

quakes from subterraneous fires, and shewn the strict similitude between the effects of artificial mines and earthquakes^z; the passage is somewhat prolix, but well worth transcribing.—“ It seems
 “ then much more likely that an earthquake
 “ should be the consequence of a sudden inflam-
 “ mation of sulphureous and bituminous steams,
 “ taking fire from an intermixture of nitre, in
 “ subterraneous caverns not far below the surface
 “ of the ground, it having been before observed
 “ that a like steam within a cloud, kindles into
 “ lightning. The violent nature of flame, in its
 “ first formation, when generated from such ma-
 “ terials, may be sufficiently known, by attend-
 “ ing to the effects of that of gunpowder fired in
 “ pieces of ordnance; or rather, in military mines,
 “ where the expansive power of the flame is able
 “ to lift up the weight of a fortress or castle, and
 “ give a terrible concussion to the strongest build-
 “ ings in its neighbourhood. Since then a small
 “ quantity of flame let loose from a small mine,
 “ in comparison of the mass of building over it,
 “ is capable of producing so great effects, what
 “ may not a far more copious flame in a large
 “ subterraneous cavern do to the earth and moun-
 “ tains over it and about it? As the flames of
 “ mines operate with a various success, as the
 “ mines are more or less confined, greater or les-
 “ ser, deeper or shallower, and according to the
 “ closeness and looseness, dampness and dryness of
 “ the powder, &c. sometimes producing no ef-
 “ fect at all, sometimes a shock only, and at o-

^z Animad. in lib. x. Diog. Laert. p. m. 1045 & seqq.

“thers the expected execution; so the flames
 “kindled from subterraneous exhalations, ac-
 “cording to the various circumstances of the ca-
 “verns and vaults, may perhaps often have no
 “sensible influence above the surface, either from
 “the laxness of the earth, through whose spira-
 “cles they may gradually escape and be dissipat-
 “ed; or their utmost consequence may be only a
 “slight shock or tremor, the incumbent weight
 “being too great to be removed; in which case
 “the flames will be reflected back, and find a
 “passage through some lateral spiracles of the ca-
 “vern: Or when the resistance above is great,
 “and they cannot otherwise escape, they may oc-
 “casion subversions, absorptions, &c. Or lastly,
 “having forced a sufficient aperture, they may
 “belch out fire and ashes, or eject sparrs, mine-
 “rals, pumice stones, and fragments of rocks,
 “&c. partly calcined, and partly melted.”

VI. And lastly, let us hear an evidence out of
 the Peripatetic school, the famous *Andreas Cæsal-*
pinus, who after having spoken of subterranean ex-
 halations, adds*, “If at any time a good quan-
 “tity of such a substance should be sublimed in-
 “to any of the regions of the earth, whose cavi-
 “ties are filled with air, and not with water; it
 “may easily be set on fire, as happens in the
 “clouds. Hence come fiery eruptions in many
 “places; hence shocks of earthquakes, and
 “oftentimes subversions, when the pores of the
 “earth are not open enough to favour the escape

* Lib. iii. peripatet. quæst. ix. sub finem.

“ of the generated blast: hence sulphureous beds
 “ and hot springs: For sulphur, bitumen, and
 “ such like inflammable bodies have their origin
 “ from concreted exhalations, which having ac-
 “ quired the igneous principle, do administer to
 “ the duration of subterraneous fires; and when
 “ the circumambient bodies become warmed by
 “ such fires, the waters which glide over them are
 “ heated also.” Which expressions, tho’ some-
 what obscure in comparison of the brighter truths
 delivered above, yet considering them the offspring
 of the *Latin* Peripatetic school, must be allowed
 to shine in some degree.

VII. I come now to the other point I proposed:
 to enforce it as a serious truth, that the stupendous
 effects of earthquakes, whether we consider them
 with regard to their immense greatness or their va-
 riety, can be no other than a work every way ade-
 quate to the infinite power of the supreme Being:
 And this perhaps may be the more easily assented
 to, if an intervention of certain active forces sub-
 ordinate to the same divine power, can be de-
 monstrated; and indeed could nothing of this kind
 be demonstrated, it would be a kind of sacrilege
 to attempt to ascribe effects worthy of the divine
 power and virtue alone, to any natural agent, al-
 though subordinate to that divine power. For
 what must such agent be? What such virtue sub-
 ordinate and contradistinct to the divine power?
 You will answer perhaps without much hesitation,
 that it must be subterraneous fire; the efficacy of
 which is but too apparent and obvious to all who

have the misfortune to be placed within the sphere of its fury.

VIII. I do not deny the stupendous energy and power which resides in fire, the most amazing of all God's creatures! It is manifest to the most vulgar eyes and the dullest senses, even to those of brutes. But when I survey it with the philosophical eye of sound reason, the immediate gift of the divinity, I am plainly convinc'd that its wonderful efficacy is no other than the very efficacy of the divine virtue alone. I have in another place analytically investigated the nature of fire, and found it to consist of two very subtile parts, but the one far less subtile than the other. The less subtile is made up of select rigid and acute particles of the terrene element, which are absolutely inert and passive; the others of the first element, are inconceivably more subtile, and extremely moveable; and these, in vertue of their perpetual activity, set the others in motion, and in this manner produce the universally visible and palpable power of fire. But should we go further, and enquire from whence this rapid agitation of the subtile particles of the first element is derived? It would be absurd to say they derived it from themselves, and equally absurd to suppose, that these, being prime particles, had it from others, prior to themselves; which if granted, the difficulty would be still the same, &c. The certain conclusion then must be, that the particles of the first element did not only once receive that actual mobility which is manifest in fire, from an incorporeal principle, prior and superior to all matter, but that it is likewise, through

through the perpetual aid of the same principle, that it is kept in constant possession of the same. Or, to express the thing more plainly, that the most subtile components of fire, primarily agitated by the divine will, do, by the same divine will, agitate the less subtile ones, and impel them against grosser bodies; and so have all the ordinary and visible effects of fire hitherto been, now are, and hereafter will be produced: In a word, that the power which we consider as proper to fire, is in reality the constant will of the Deity, whereby he was once pleased, that the most subtile, and by their means also the less subtile parts of fire should be kept in perpetual motion, and that by the mediation of both, all the effects of fire should ensue; and therefore that it will be in vain to imagine that there is any virtue, subordinate to the Deity, that can any ways move, or operate upon, the parts of fire, but this divine one alone.

IX. The most subtile parts of fire are then agitated merely by the divine will; and by them the grosser *spiculæ* of the same body: And, by means of the *spiculæ*, rapidly impelled on yet grosser bodies, they are kindled, melted, calcin'd, and burnt to ashes; and grand masses receive impulses, and are moved in various directions; and all the stupendous effects of earthquakes, before related, are brought to pass. God, according to his good pleasure, and the eternal order by him established, makes use of various and infinite means (yet of none derived but from himself) as passive instruments, but never employs any other really active vertue, subordinate to himself. For to what

end can such agents exert themselves? To what can they contribute, when it is his omnipotent virtue alone, that can impress upon their several members the impetus requisite to the office of their destination, whether immediately, or by the intermediation of others, variously passive, but no ways active, or endued with a virtue contradistinct to that of the prime mover? So that it must be insisted upon again and again, that it is the will of the omnipotent Creator alone, that acts and moves, and by moving governs and regulates all things in the universal world, and that immediately, in consequence of a proper virtue: That is without the intervention of any other active virtue of any creature whatever, though indeed mediately, in regard to the action of that only divine virtue, with respect to the disposition, aptitude, and capacity of various recipients.

X. But could not the great Creator of the universe communicate to fire an active power of burning, &c. in vertue of which it might afterwards perform all its usual effects, and, of itself, bring on earthquakes?

I answer: I know very well that with many, this is the main obstacle which hinders their assent to the philosophical truth which I contend for, tho' clear enough in itself. I am, I own, very desirous of shewing the impossibility of communicating such active forces to substances merely corporeal. I intreat therefore my readers attention to what I have already said, as well as to what I am going to say concerning the power of fire to burn, &c.

Unless

Unless I were to express the definition of fire in abstract terms, instead of considering it under any real agitation and motion, obvious partly to the senses, and partly to the imagination, I must be obliged, with most modern philosophers, to suppose a twofold motion, one of the grosser and terrene particles piercing, cutting, breaking and dissolving the continuity of other bodies, and inflicting the most exquisite pains on sensitive bodies; and another, of the inconceivably subtile parts, swiftly pervading in all directions the pores of all bodies, not previously occupied by themselves in consort with their terrene *spiculae*, and that not only without any detriment, but even sensible perception. It is clear and manifest that the impetus of the former particles, since it is passively dependent on the supposed swift agitation of the latter, cannot constitute any active power in fire. Wherefore, if there were any active power at all in fire, it must be ascribed to the agitation of its very subtile parts (supposing it has none more subtile still than those, &c. to do which would be weak and absurd,) which is the same as to say it is communicated to it by God himself. Now such agitating force could be communicated to it no otherwise than either by giving to the particles a power of agitating themselves (which is absurd to all sound reason, and even to the Peripatetics themselves) or by willing that they should be so agitated. But since to be agitated implies something passive, and in this instance, dependent inevitably on the divine will; it is manifest that in fire there is no active power, properly so called, besides the sole efficacy

efficacy of the divine will, whereby that more subtile part of it communicates motion to the groffer particles, impelling them upon other bodies, and so producing other consequent effects; in respect of which, the motion of the *spiculæ* may indeed be called active, as also that of the subtile parts in respect of the motion of the *spiculæ*, though they are all of them absolutely passive. It is then the perfection of the divine power alone, not to stand in need of any intrinsic motive power, and as such it is absolutely and truly active, and efficiently productive of the motions essential to fire, and of innumerable others thereon depending.





OF THE
N A T U R E
O F
EARTHQUAKES.

*More particularly of the Origin of the Matter of
them, from the Pyrites alone.*

I Have elfewhere ^a shewn that the breath of the pyrites is sulphur *ex tota substantia*: also that it naturally takes fire of itself. Again that the material cause of thunder and lightning, and of earthquakes, is one and the same; *viz.* the inflammable breath of the pyrites. The difference is, that one is fixed in the air; the other underground: of which last, these I think are sufficient arguments. A thing burnt with lightning smells of very brimstone; again, the subtilty and thinness of the flame; also the manner of its burning, which is often observed to be *particulatim*, or in small spots, vapour-like. And of earthquakes,

^a *De fontibus medicatis Angliæ.*

the sulphureous stink of waters smelt before, and of the very air itself after them; of which innumerable instances occur in the relations of them.

They also agree in the manner of the noise, which is to be carried on, as in a train fired; the one rolling and rattling through the air, taking fire as the vapours chance to drive; as the other fired under ground, in like manner moves with desultory noise, as it shall chance to be continued.

That the earth is more or less hollow, is made probable by what is found every where in mountains, *viz.* natural cavities or chambers, which the miners of the north call *self-opens*. These they meet with very frequently, some vastly great, and others less, running with small sinus's. And I doubt not, upon diligent inquiry, a great catalogue of such might be had, discovered in the memory of man: besides many there are, which are known to be open to the day, and to discover themselves without digging, as *Pool's Hole*, *Oakie Hole*, &c. Again, the great and small streams, which do arise from under the mountains, do evince the hollowness and sinuousness of them. Add to these, that many sinus's are made in that instant, and are continued by the explosion and rending of the first matter fired; which may, and do very probably, close again, when the force of that explosion is over; but are sufficiently open to continue the earthquake.

That these subterraneous cavities are at certain times, and in certain seasons full of inflammable vapours, the damps in our mines sufficiently witness;

ness; which fired, do every thing as in an earthquake, save in a lesser degree.

Now, that the pyrites alone (which is our present task) of all the known minerals, yields this inflammable vapour, I think is highly probable for these reasons.

I. Because no mineral or oar whatsoever is sulphureous, but as it is wholly, or in part a pyrites: and although this does contradict the general opinion of the chymists; yet they must excuse me if I dissent from them in this particular: for where any of them shall find me brimstone naturally contained in an ore; there, I am very forward to believe, I shall find them iron also, by the loadstone; so that betwixt us we shall have discovered the pyrites disguised in that ore or mineral. I have carefully made the experiment in very many of the fossils of *England*, and do find them all to contain *iron*, wherever *brimstone* is, as I have elsewhere declared.

II. Because there is but one species of brimstone, that I know of, at least with us in *England*: And since the pyrites naturally and only yields it, it is but reasonable, wherever brimstone is found, though in the air, or under ground in vapour, to think that that also proceeds from it.

If it be objected, that there is a sulphur vive, or natural brimstone, which is no pyrites; I answer, that I am not willing to grant this, but do take all pure sulphur to have been once produced by the fire: for what is found in and about the burning mountains, is certainly the effects of sublimation: and those great quantities of it, said to be
found

found about the skirts of volcano's, is only an argument of the long duration and vehemence of those fires.

If it be further objected, that the sulphur vive indeed, or ruff brimstone, as they call it, had from *Hecla* and *Italy*, is opaque, and agrees not with the transparent and amber-like sulphur vive of the ancients, so that the mistake is in the drug-gifts, that we have not right natural brimstone; I reply, that grant the difference, yet it does not follow, that that also was produced by sublimation, no more than that the stalactites, or water-wrought stone, is not so made, for that some of it is found opaque, and some chrystalline.

But this we will grant; that possibly the pyrites of the volcano's or burning mountains may be more sulphureous than ours. And indeed it is plain, that some of ours in *England* are very lean, and hold but little sulphur; others again very much.

And this may be one reason, why *England* is so little troubled with earthquakes; and *Italy* and almost round the *Mediterranean Sea* so very much.

Another reason is, the paucity of pyrites in *England*; where they are indeed, some little in all places, but mostly, *sparsim*; and if perchance in *beds*, those are comparatively thin, to what probably they were in the burning mountains, as the vast quantity of sulphur from thence sublimed, doth seem reasonably to imply. Also if we compare our earthquakes, and our thunder and lightning with theirs; there it lightens almost daily, especially in summer time, here seldom; there thun-

der and lightning is of long duration, here soon over; there the earthquakes are frequent, long and terrible, with many paroxysms in a day, and that for many days; here very short, a few minutes, and scarce perceptible. To this purpose the subterraneous cavities in *England* are small, and few, compared to the vast vaults in those parts of the world; which is evident from the sudden appearance of whole mountains and *islands*.

If yet it shall be insisted upon, that there are other inflammable minerals besides the pyrites; we grant there are so, but, by the providence of God, not to be found in *England*, that I know of, and not in any quantity in any place of the world, that I can learn; which is well for mankind, because they are very poisons, as the orpiments; but they are all specifically distinct from brimstone, which, as we have shewn, no ore yields but iron; so that *Nero* (as *Pliny* testifies, who was of his time and his court) caused them to be wrought in quantity, but they would not turn to account. And, by the by, some authors have assigned this as a good reason, against any medicine that shall be made out of gold, as fond as we are of an *aurum potable*, as having naturally a deleterious quality: but this is besides my purpose.

Of the spontaneous firing of the Pyrites.

IF it shall be objected, that no body is kindled by itself: I answer, that it seems to me apparently otherwise; for that vegetables will heat, and take fire of themselves, as in the frequent instance

stance of wet hay; and animals are naturally on fire, and a man doth then sufficiently demonstrate it when he is in a fever. But amongst minerals, the pyrites, both in gross and in vapour, is actually of its own accord fired. Dr. *Power* has actually recorded at large in his *Micrographia*^b, a famous instance of it; and the like not very rarely happens. And that damps naturally fire of themselves, we have the general testimony of miners and of the same author^c.

Again, the volcano's all the world over, argue as much: for we, with great probability, believe them to be mountains made up in great part of pyrites, by the quantities of sulphur thence sublimed, and the application of the loadstone to the ejected cinder. I go further.

That these volcano's were naturally kindled of themselves, at or near the creation, is probable, because there is but a certain known number of them, which have all continued burning beyond the memoirs of history: few or none of them, that I know of, have even totally decayed or been extinct, unless possibly by the submerfion of the whole; being absorb'd into the sea: though they do indeed burn more fiercely sometimes, than at others, for other reasons. So that it seems to me as natural to have actual fire in the terrestrial world from the creation, as to have sea and water.

Again, if these volcano's did not kindle of themselves, what cause can we imagine to have done it? Of the sun; we answer, *Hecla* placed in so extreme cold a climate, was kindled, for ought

^b *Power Microg.* p. 61. ^c *Id.* p. 181.

I can see by the natural history of both, as soon as *Ætna*, or *Fuegos*, or the most southerly. Not the accidents happening from man; for if man was, as we must believe, created solitary and topical, they were none of his kindling, because they seemed to be fired before the world was overpeopled: besides, they are mostly the very tops of vast high mountains, and therefore the most unfit for the habitation of man.

If we say lightning and thunder, and earthquakes, we beg the question; for the cause of one is the cause of the other, and they are one and the same.

It remains therefore, very probably, that they were kindled of themselves.

I for my part know no subject in the whole mineral kingdom so general and lasting for the fuel of these mountains, as the pyrites; which I have said alone to yield sulphur, and naturally resolves itself into it, by a kind of vegetation.

About the durable burning of the pyrites, these are instances. *Scotch* coal hath less of the pyrites in it, being mostly made up of coal bitumen, and therefore it burns and consumes quickly, and leaves a white cinder. Sea-coal, or that coal which comes from *Newcastle* by sea to us, and for that reason so called, burns slowly; and the *Sunderland* sea-coal so slowly, that it is said by proverb, *to make three fires*: this hath much pyrites mixed with it, and burns to a heavy redish cinder, which is iron, by the magnet. But I have seen, and have a specimen by me of a coal from *Ireland*, the proprietor of the pits is Sir *Christopher Wandsford*,
F which

which is said to be so lasting, that it will continue twenty four hours red hot, and almost keep its figure. This seems to be in a great part pyrites by the weight and colour.

There are two sorts of instances, besides the arguments I have already urged, which to me are alone sufficiently convincing, and very much favour the opinion I have offered; that thunder and lightning owe their matter to the sole breath of the pyrites. And although I am as loth, and as backward as any man, to give credit to such instances, which seem rather prodigies, than the phænomena of nature; yet because they often occur in history, it is at least fitting to bring them under further inquiry and examination, that if they can be confuted as false, so much may be done for posterity; and that we at least may not leave upon our registers matters of fact not true, if they can be fairly set aside.

The first sort of them are those which tell us of iron to have fallen in great masses, and also in powder, after the manner of rain, out of the air.

In a part of *Italy* it rained iron in such a year, and in *Germany* a great body of iron-stone fell at such a time: The like *Avicenn* affirms. *Julius Scaliger* says he had by him a piece of iron which was rained in *Savoy*, where it fell in divers places. *Cardan* reports 1200 stones to have fallen from heaven, and one of them weighed 120 pounds, some of them 30 pounds, some 40, very hard, and of the colour of iron.

Now, that which is very remarkable, says *Gilbert*, where those instances are reckoned up, and

a very probable argument for the truth of such like instances, is, that it is no where recorded, that it ever rained gold or silver ore, or tin or lead; but copper hath been also said to have fallen from the clouds.

And here I must note by the by, that wherever the pyrites is mentioned by the ancients, it is always to be understood of the *copper pyrites*; they scarce having had any knowledge of the iron pyrites: And therefore the raining of copper makes it yet more probable, because of its great affinity with iron, which I shall have occasion on some other time to discourse of.

Now this *Ferrum* or *Æs Nubegnum*, if there was ever any such, was concreted of the breath of the pyrites, which we have elsewhere shewn to be the sulphur *ex tota substantia*.

The other instance, which I say is owing to our registers, is of lightning being magnetic^d.

This I am sure of, I have a petrified piece of ash which is magnetic; that is, the pyrites *in succo*; which makes it probable it may be magnetic also in vapour.

^d Philosoph. Transact. N° 127.





DISCOURSES
CONCERNING
EARTHQUAKES.

*Vidi ego quod fuerat quondam solidissima tellus
Esse fretum; vidi fractas ex littore terras;
Et procul a pelago chonchæ jacuere marinæ,
Et vetus inventa est in montibus anchora summis;
Quodque fuit campus, vallem decursus aquarum
Fecit, et eluvie mons est deductus in æquor.*

Ovid. Metam. Lib. xv.

PROPOSITIONS.

- I. **T**Here are found in most countries of the earth, and even in such where it is somewhat difficult to imagine, by reason of their vast distance from the seas or waters, how they should come there, great quantities of bodies, resembling both in substance and shape, the shells of divers sort of shell-fishes; and many of them so exactly, that any one that knew not from whence they came, would without the least scruple, firmly believe them to be the shells of

of such fishes : but being found in places so unlikely to have produced them, and not conceiving how else they should come there ; they are generally believed to be real stones formed into those shapes, either by some plastic virtue inherent in those parts of the earth, which is extravagant enough, or else by some celestial influence or aspect of the planets operating at a distance upon the yielding matter of the parts of the earth, which is much more extravagant. Of this kind are all those several sorts of oyster-shells, cockle-shells, muscle-shells, periwinkle-shells, &c. which are found in *England, France, Spain, Italy, Germany, Norway, Russia, Asia and Africa*, and divers other places ; of which we have very good testimony from authors of good credit.

II. There often have been, and still are daily found in other parts of the earth, buried below the present surface thereof, divers sorts of bodies, besides such as I newly mentioned, resembling both in shape, substance, and other properties, the parts of vegetables, having the perfect rind or bark, pith, pores, roots, branches, gums, and other constituent parts of wood ; and though in another posture, lying for the most part horizontal, and sometimes inverted, and much different from that of the like vegetables when growing ; and wanting also for the most part, the leaves, smaller roots and branches, the flower and fruit, and the like smaller parts, which are common to trees of that kind : of which sort is the *lignum fossile*, which is found in divers parts of *England, Scotland, Ireland*, and various parts of

Italy, Germany, the Low-Countries, and indeed almost in every country of the world.

III. There are often found in divers other parts of the earth bodies, resembling the whole bodies of fishes, and other animals and vegetables, or the parts of them, which are of a much less permanent nature than the shells abovementioned; such as fruits, leaves, barks, woods, roots, mushrooms, bones, hoofs, claws, horns, teeth, &c. But in all other properties of their substance, save their shape, are perfect stones, clays or earths, and seem to have nothing at all of figure in the inward parts of them. Of this kind are those commonly called thunder-bolts, helmet-stones, screw-stones, wheel-stones, &c.

IV. The parts of the earth in which these kinds have been found, are some of them some hundred of miles distant from any sea, as in several hills of *Hungary*, the mountain *Taurus*, the *Alpes*, &c.

V. Divers of those parts are many scores, nay some many hundreds of fathoms above the level of the surface of the next adjoining sea, they having been found in some of the most inland, and on some of the highest mountains in the world.

VI. Divers other parts where these substances have been found, are many fathoms below the level both of the surface of the next adjoining sea, and of the surface of the earth itself, they having been found buried in the bottoms of some of the deepest mines and wells, and inclosed in some of the hardest rocks and toughest metals. Of this we have continual instances in the deepest lead and tin-mines, and a particular instance in the well dug

dug in *Amsterdam*; where at the depth of 99 feet was found a layer of sea shells mixed with sand, of four feet thickness; after the diggers had passed through seven foot of garden-mould, nine foot more of black peat, nine foot more of soft clay, eight of sand, four of earth, ten of potters clay, four more of earth, ten foot more of sand, upon which the stakes or piles of the *Amsterdam* houses rest; then two foot more of potters-clay, and four of white-gravel, five of dry earth, one of mix'd, fourteen of sand, three of sandy clay, and five more of potters-clay mixed with sand. Now below this layer of shells, immediately joining to it, was a bed of potters-clay of no less than 102 foot thick.

VII. There are often found within the bodies of very hard and close stone, as marbles, flints, *Portland* and *Purbeck* stones, &c. which lye upon, or very near to the surface of the earth, great quantities of these kind of figured bodies or shells; and there are many of such stones which seem to be made of nothing else.

These phænomena, as they have hitherto much puzzled all natural historians and philosophers to give an account of them, so in truth are they in themselves so really wonderful, that 'tis not easy, without making multitudes of observations, and comparing them very diligently with the histories and experiments that have been already made, to fix upon a plausible solution of them. For as on the one side, it seems very difficult to imagine that nature formed all these curious bodies for no other end, than only to play the mimick in the

mineral kingdom, and only to imitate what she had done for some more noble end, and in a greater perfection in the vegetable and animal kingdoms; and the strictest survey that I have made, both of the bodies themselves, and of the circumstances obvious enough about them, do not in the least hint any thing else; they being promiscuously found of any kind of substance, and having not the least appearance of any internal or substantial form, but only of an external or figured superficies. As, I say, 'tis something harsh to imagine that these thus qualified bodies should, by an immediate plastic virtue, be thus shaped by nature, contrary to her general method of acting in all other bodies; so on the other side, it may seem at first hearing somewhat difficult to conceive how all those bodies, if they either be the real shells or bodies of fish, or other animals or vegetables, which they represent, or an impression left on those substances from such bodies, should be in such great quantities transported into places so unlikely to have received them from any help of man, or from any other obvious means.

The former of these ways of solving these phænomena I confess I cannot, for the reasons I now mentioned, by any means assent unto; but the latter, tho' it has some difficulties also, seems to me not only possible, but probable.

The greatest objections that can be made against it, are *1st*, By what means those shells, woods, and other such like substances, if they really are the bodies they represent, should be transported to, and buried in the places where they are found?

And

And 2^{dly}. Why many of them should be of substances wholly differing from those of the bodies they represent; there being some of them which represent shells of almost all kinds of substances, clay, chalk, marble, soft stone, harder stone, marble, flint, marchasite, ore, &c.

In answer to both which, and some other of less importance, which I shall afterwards mention, give me leave to propound these following propositions, which I shall endeavour to make probable. Of these in their order.

I. All, or the greatest part of those curiously figured bodies, found up and down in various parts of the world, are either those animal or vegetable substances they represent, converted into stone, by having their pores filled up with some petrifying liquid substance, whereby their parts are, as it were, lock'd up and cemented together in their natural position and contexture; or else they are the lasting impressions, made on them at first, whilst a yielding substance, by the immediate application of such animal or vegetable body, as was so shaped; and that there was nothing else concurring to their production, save only the yielding of the matter to receive the impression, such as melted wax affords to the seal: or else a subsiding or hardning of the matter, after by some kind of fluidity it had perfectly filled or inclosed the figuring vegetable or animal substance, after the manner as a statue is made of plaister of *Paris*, or alabaster dust beaten, and boiled, mixed with water, and poured into a mould.

II. There

II. There seems to have been some extraordinary cause which did concur to the promoting of this coagulation or petrification; and that every kind of matter is not of itself apt to coagulate into a strong substance, so hard as we find most of those bodies to consist of.

III. The concurrent causes assisting towards the turning of these substances into stone, seem to have been one of these; either some kind of fiery exhalation, arising from subterraneous eruptions or earthquakes; or, secondly, a saline substance, whether working by dissolution and congelation, or crystallization, or else by præcipitation and coagulation; or thirdly, some glutinous or bituminous matter, which upon growing dry or settling, grows hard, and unites sandy bodies together into a pretty hard stone; or fourthly, a very long continuation of these bodies under a great degree of cold and compression.

IV. Waters themselves may in tract of time be perfectly transmuted into stone, and remain a body of that constitution, without being reducible by any art yet commonly known.

V. Divers other fluid substances have, after a long continuance at rest, settled and congealed into much more hard and permanent substances.

VI. A great part of the surface of the earth hath been since the creation transformed and made of another nature; namely many parts which have been sea are now land, and divers other parts are now sea which were once a firm land; mountains have been turned into plains, and plains into mountains, and the like.

VII. Di-

VII. Divers of these kinds of transformations have been effected, in these islands of *Great Britain*; and 'tis not improbable but that many very inland parts of this island, if not all, may have been heretofore all covered with the sea, and have had fishes swimming over it.

VIII. Most of those inland places, where these kind of stones are, or have been found, have been heretofore under water; and either by the departing of the waters to another part or side of the earth, by the alteration of the center of gravity of the whole bulk, which is not impossible; or rather by the eruption of some kind of subterraneous fires or earthquakes, whereby great quantities of earth have been raised above the former level of those parts, the waters have been forced away from the parts they formerly covered, and many of those surfaces are now raised above the level of the waters surface, many scores of fathoms.

IX. It seems not improbable that the tops of the highest and most considerable mountains in the world have been under water, and that they themselves seem most probably to have been the effects of some very great earthquake, such as the *Alpes* and *Apennine* mountains, *Caucasus*, the pike of *Teneriffe*, the pike in the *Tercera's* and the like.

X. It seems not improbable, but that the greatest part of the inequality of the earth's surface may have proceeded from the subversion and tumbling thereof, by some preceding earthquakes.

XI. There have been many other species of creatures in former ages, of which we can find none at present; and 'tis not unlikely also but that there
may

may be divers new kinds now, which have not been from the beginning.

There are some other conjectures of mine yet unmentioned, which are more strange than these, which I shall defer the reciting of at present, because, though I have divers observations concurring; yet having not been able to meet with such as may answer some considerable objections that they are liable to, I will rather endeavour to make probable those already mentioned, by setting down some of those observations (for it would be tedious to insert them all) I have collected both out of authors, and from my own experience.

The first was, that these figured bodies dispersed over the world, are either the beings themselves petrified, or the impressions made by those beings. To confirm which, I have diligently examined many hundreds of these figured bodies, and have not found the least probability of a plastic faculty. For first, I have found the same kind of impression upon substances of an exceeding different nature; whereas nature in other of her works, does adapt the same kind of substances to the same shape: the flesh of a horse is differing from that of a hog, or sheep, or from the wood of a tree, or the like; so the wood of box, for instance, is differing from the wood of all other vegetables; and if the outward figure of the plant or animal differ, to be sure their flesh also differs: and under the same shape you always meet with substances of the same kind; whereas here I have observed stones bearing the same figure, or rather impression, to be of hugely differing natures; some
of

of clay, some of chalk, some of spar, some of marble, some of a kind of freestone, some like crystals or diamonds, some like flints, others a kind of marchasite, others a kind of ore. Nay in the same figured substance I have found divers sorts of very differing bodies or kinds of stone, so that one has been made up partly of stone, partly of clay, and partly of marchasite, and partly of spar, according as the matter chanced to be jumbled together, and to fill up the mould of the shell.

Another circumstance which makes this conjecture the more probable, is, that the outward surface only of the body is formed, and that the inward part has nothing of shape that can reasonably be referred to it; whereas we see, that in all other bodies that nature gives a shape to, she figures also the internal parts, or the very substance of it, with an appropriate shape. Thus in all kinds of minerals, as spars, crystals, and divers of the precious stones, ores, and the like, the inward parts of them are always correspondent to the outward shape; as in spar, if the outward part be shaped into a rhomboidical parallelopiped, the inward part of it is shaped in the same manner, and may be cleft out into a multitude of bodies of the like form and substance.

Another circumstance is, that I have in many found the perfect shell inclosed, which I have sometimes been able to take out intire, and found to be, both by its substance and shape, and reflective shining, and the like circumstances, a real shell of a cockle, perriwinkle, muscle, or the like.

And

And further, I have found in the same place divers of the same kinds of shells, not filled with a matter that was capable of taking the impression, but with a kind of sandy substance, which lying loose within it, could be easily shook out, leaving the inclosing shell perfectly intire and empty; others I have seen which have been of black flint, wherein the impression has been made only of a broken shell, which stuck also in it; the other part of the surface of that stone, which was not within the shell, remaining only formed, like a common flint.

And, which seems to confirm this conjecture, much more than any of the former arguments, I had this last summer an opportunity to observe upon the *south* part of *England*, in a clift whose bottom the sea washt, that at a good height in the clift above the surface of the water, there was a layer, or vein of shells, which was extended in length for some miles; out of which layer I digged, and examined many hundreds, and found them to be perfect shells of cockles, perriwinkles, muscles, and divers other sorts of small shell-fishes; some of which were filled with the sand with which they were mixed; others remained empty, and perfectly intire. From the sea water's washing the under part of this clift, great quantities of it do every year tumble or founder down, and fall into the salt water, which are washed also by the several mineral waters issuing out at the bottom of the clifts. Of these foundered parts I examined very many parcels, and found some of them made into a kind of hardened mortar, or very soft stone, which

which I could easily with my foot, and even almost with my finger, crush in pieces: others that had laid a longer time exposed to the vicissitudes of the rising and falling tides, I found grown into pretty hard stones; others that had been yet longer, I found converted into a very hard stone, retaining exactly the shape of the inclosing shell: and in the part of the stone which had encompassed the shell, there was left remaining the perfect impression and form of the shell; the shell itself continuing, as yet, of its natural white substance, tho' much decayed or rotted by time: but the body inclosing and included by the shell, I found exactly stamp'd like those bodies whose figures authors generally affirm to be the product of a plastic or vegetative faculty working in stones.

Another argument, that these petrified substances are nothing but the effects of those shells being filled with some petrifying substances, is this, that among those which are called *Cornua Ammonis*, or serpentine stones, found about *Keinsham*, and in several other parts of *England*, and in other countries, as the *Balnea Bollenfia*, which are indeed nothing else but the moulding off from a kind of shell which is shaped much like a *nautilus* shell, the whole cavity being separated with divers small valves or partitions, much after the same manner as those shells of the *nautilus* are commonly observed to be. Among these stones, I say, I have, upon breaking, found some of the cavities between those partitions remain almost quite empty; others I have found lined only with a kind of tartareous, or rather crystalline substance, which has stuck to

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the

the sides, and been figured like tartar, but of a clear and transparent substance like crystal; whereas others of the cavities of the same stone, I have found filled with divers kinds of substances very differing: whence I imagine those tartareous substances to be nought else but the hardening of some saline fluid body, which might soak in through the substance of the shell. Others of these I have, which are quite of a transparent substance, and seem to be produced from the petrification of the water that had filled them: others I have found filled with a perfect flint, both which I suppose to be the productions of water petrified: and I may perhaps hereafter make it probable, that all kinds of flints and pebbles have no other original.

I could urge many other arguments to make my first proposition probable, that all those curiously shaped stones, which the most curious naturalists most admire, are nothing but the impressions made by some real shell, in a matter that at first was yielding enough, but which is grown harder with time. To this very head also may be referred all those other kinds of petrified substances, as bones, teeth, crabbs, fishes, wood, moss, fruit, and the like; some of all which kinds I have examined, and by very many circumstances, too long to be here inserted, judge them to be nothing else but a real petrification of those substances they resemble.

My second proposition will not be difficult to prove, that if these be the effects of petrification or coagulation, it must be from some extraordinary cause; and this because we find not many experiments of producing them when and where we will: besides

we find that most things, especially animal and vegetable substances, after they have left off to vegetate, do soon decay, and, by divers ways of putrefaction and rotting, lose their form and return to dust; as we find wood, whether exposed to the air or water, in a little time to waste and decay, especially such as is exposed to the alteration of both, and even in those places where these petrified substances are to be met with. The like we find of animal substances; and we have but some few experiments of preserving those bodies, to make them as permanent as stone, and few of making them into a substance of the like nature.

The third thing therefore, which I shall endeavour to shew, is, that the concurring causes to these petrifications, seem to be either some kind of petrifying water, or else some saline or sulphureous mixture, with the concurrence of heat, from some subterraneous fire or earthquake; or else a very long continuation of those bodies under a very great degree of cold, and compression, and rest. That petrifying waters may be able to convert both animal and vegetable substances into stone, I could, besides several trials of my own, bring multitudes of relations out of natural historians: but these are so common in almost all countries, and so commonly taken notice of by the curious, that I need not instance. *Camden* and *Speed* will tell you of abundance here in *England*, as the *Peak* in *Derbyshire*, and in several other subterraneous caverns in *England*. The water itself does, by degrees, produce several conical pendulous bodies of stone, shap'd and hanging like icicles from the roof

of the vault; and dropping on the bottom, it raises up also conical spires, which, by degrees, endeavour to meet the former pendulous *striae*. And indeed I have generally observed it, that wherever there is a vault made with lime under ground, into which the rain-water, soaking through a pretty thickness of ground, does at last penetrate through the arch: I have in several places, I say, observed, that that water does incrustate the roof with stone, and in many places of it generate small pendulous icicles. This water I have found in a little time to incrustate sticks, or the like vegetable substances, with stone, and in some places to penetrate into the pores of the wood, filling them up with small cylinders of stone. This I have observed also in several of the arches of *St. Paul's* church, which have been uncovered and laid open to the rain, though there be no earth for it to soak through. And altho' I have never yet been able to petrify a stick throughout, yet I have now by me several pieces, that retain so perfectly all the figure of the wood, and are yet so perfectly, in all other properties, stone, that I find not the least reason of doubt to believe, that those pieces have been actual wood; having still the bark, the clefts, the knots, the grain, the pores, and even those too which, for their smallness, I have elsewhere called microscopical; tho' I confess some of those more perfect pieces seem to have been petrified from some more subtle and insinuating petrifying water, than those I newly mentioned: and 'tis not improbable but that some subterraneous steams and heat may have contributed somewhat towards this effect. But first I shall endeavour

endeavour to make it probable, that these petrified bodies may have been placed in those parts where they are found, by some kind of transformation wrought on the surface of the earth, by some earthquake: and to this end I shall by and by mention some strange alterations that have been made by earthquakes, after I have first made probable my fourth conjecture.

The fourth proposition therefore to be explained and made probable is, that waters themselves of divers kinds, are, and may have been transmuted perfectly into a stony substance, of a very permanent constitution, being scarcely reducible again into water by any art yet commonly known: and that divers other liquid or fluid substances have in tract of time settled and congealed into much more hard, fixt, solid and permanent forms than they were of at first.

The probability of which proposition may appear from these particulars.

I. That almost in all streams and running waters there is to be found great quantities of sand at the bottom, many of which sands both by their figure in the microscope, and transparently, seem to have been generated out of the water.

First, I say, that their transparency which they discovered in the microscope, is an argument, because I believe there is no transparent body in the world, that has not been reduced to that constitution, by being some ways or other made fluid; nor can I indeed imagine how there should be any. All bodies, made transparent by art, must be reduced into that form first; and therefore 'tis

not unlikely but that nature may take the same course ; but this, as only probable, I shall not insist on. Next, I say, that the figures of divers of them in the microscope discover the same things ; for I have seen multitudes of them curiously wrought and figured like crystals or diamonds ; and I cannot imagine by what other instrument nature should thus cut them, save by crystallizing them out of a liquid or fluid body ; and that way we find her to work in the formation of all those curious, regular figures of salts, and the vitriols, as I may call them, of metals and divers other bodies, of which chymistry affords many instances. Sea-salt and sal-gem crystallizes into cubes or four-sided parallelopipeds ; nitre into triangular and hexangular prisms ; alum into octahedrons ; vitriols into various kinds of figures, according to the various kinds of metals dissolved, and the various menstruums dissolving them ; tartars also, and candyings of vegetables are figured into their various regular shapes from the same method and principle : and in truth, in the formation of any body out of this mineral kingdom, whose origin we are able to examin, we may find that nature first reduces the bodies to be wrought into a liquid or soft substance, and afterwards forms and shapes it into this or that figure. But this argument drawn from the sand, found in all running streams, I shall not insist on, because some imagine it to be only washed off from the land and shores the rivers passed over, and perhaps much of it may : but yet that sand may be made of clear water, my second argument will manifest, and that is this :

That

That 'tis a usual experiment in the making of salt in the salterns, by the boiling up, or evaporating away the fresher part of the sea-water, to collect great quantities of sand at each corner of the boiler; which after it has been well wash'd with fresh water, is, in all particulars, a perfect sand; and yet the water is so ordered before it is put into the boiler, that nothing of sand or dregs can enter with it, the brine being first suffered to stand a good while and settle in a very large vat, so that all the sand and dregs may sink to the bottom; after which the clearer water at the top is drawn off, and suffered to run into the boiler. 'Tis not impossible perhaps, but that substance which made the sand, might be dissolved in the water, and afterwards by evaporation coagulated; which if so, makes not at all against, but rather argues strongly for my fourth proposition.

But that the other solution is something more probable, namely, that 'tis made out of the very substance of the water itself, this third argument will make probable; and that is, that any water, of what kind soever, though never so clear and insipid, may, by frequent distillations, be all of it perfectly transmuted into a white insipid calx, not again dissolvable in water, and in nothing differing from the substance of stone. This I have been assured by an eminent physician, who has divers times made trial of it with the same success. If therefore the whole body of any water may, by so easy an operation, in so very short a time, be transmuted into a stony substance, what may not nature do,

that can take her own time, and knows best how to make use of her own principles?

But, fourthly, we have many instances, by which we are assured that nature really does change water into stone, both by forming in a little time, considerable stones out of the distilling drops of water soaking through the roofs of caves and subterraneous vaults, of which we have very many instances here in *England*; as, to name one for all, at the *Peak* in *Derbyshire*, the pendulous cones of this petrified substance directly point at, and oftentimes meet and rest upon the rising spires, generated by the drops of water trickling through the roof, as I mentioned before.

And, fifthly, there are divers other waters which we need not seek after in caves that have a petrifying virtue, and incrustate all the channel they pass through, and the substances soak'd in them, with stone; these are so common almost in all places, that I need not instance in any; only I cannot pass by one, taken notice of by *Kircher*, being observations made by himself, and it has in it two circumstances very considerable; the first is, that vegetables should grow so plentifully in a very hot water; the second, that only such herbs as grew in it, and not such as were steeped in it, will perfectly, after drying, be turned into stone, of which I shall have occasion to make more use. I shall give the history in his own words^a. “*Hæc experientia didici in itinere meo Hetrusco, in quo prope Roncolanum, Senensis territorij oppidum (a town near Siena in Tuscany) duos fontes calidos observavi, quorum aqua per*

^a Mund. subterr. lib. v. sect. 2. parag. 7.

canales ad molares rotas vertendas ducebatur. In hisce canalibus cyperus, junci, ranunculus similesque herbæ tanta adolescebant fecunditate, ut quotannis eas, ne aquæ motum inturbarent, extirpare oporteret: extirpatas vero projectasque in vicinum locum, herbas omnes in lapidem conversas, non sine admiratione spectavi. Cujus rei causam cum a molitoribus quærerem; responderunt aquas istiusmodi hujus virtutis esse, ut quæcunque inter canales, aut ipsâ aquâ excreverint herbæ, mox ac extirpatæ fuerint, lapidescant; quæcunque vero extra aquam, in campis patentibus excreverint herbæ, istas extirpatas nunquam lapidescere. I pass by his reasons and explications, because I think them very little to the purpose: but the observations themselves are very considerable, and serve for the explaining of several phænomena I have observed in petrified bodies, as I shall endeavour hereafter to shew, as in corals, both white and red, and the several rarities of them; in corallines also, and petrified mushrooms, of each of which I have examined a very great variety. But this only by the by.

Sixthly, therefore 'tis observable that these petrifying waters are for the most part very clear and limpid; so that to the sight not to be distinguishable from other water, but only by the effects; and therefore, by the newly mentioned observations of *Kircher*, we find that vegetables, which upon drying, turned into stone, whilst green and growing, flourished and spread faster than others: so that the petrifying substance pass through the finest and closest pores of the living vegetables, and therefore must certainly be very intimately mixed with the water

that could not be separated by so fine and curious strainers.

But, seventhly, to confirm this proposition yet farther, there are found in several parts of the earth such waters as will be entirely converted into stone. Of this kind there are several histories in the newly mentioned book, which I pass over, and shall only take notice of one for all, and that is an account sent to the *Roman* college of Jesuits from the masters, surveyors and clerks of the *Hungarian* mines, in answer to some queries propounded to them. To the query concerning the properties and metallick experiments about mineral waters, they answer ^b. *Datur in fodinis aquæ genus quod in figuram saccabaro haud absimilem degenerat, videlicet in lapillos albos.*

And again, from another prefect of the imperial mines in *Hungary*, in answer to the same query, we have this account ^c. *Reperitur quoque aqua quædam alba quæ in lapidem durum abit. Si vero hæc aqua ante suam coagulationem mineram cupream transiverit, tunc generatur ex ea lapis qui Malockites vocatur: quando vero aqua illa perfluit cupream mineram continentem argentum, fiet ex ea pulcher lapis ceruleus, similis Turcoidi. Hæc aqua autem nullibi frequentius reperitur, quam in mineris lapidibus siliceis copiosis, et cuprum cum argento continentibus.* Whence I am apt to think, and I have many observations and arguments to prove my conjecture,

That, eighthly, all kinds of talk and spar, most ores and marchasites, *Alumen plumeum* and *Abestus*, fluors, crystals, *Cornish* diamonds, amethysts, and

^b *Kircher. mund. subterr. p. 183.* ^c *Id. p. 185.*

divers other figured mineral bodies, may be generated from their crySTALLISATION, or coagulation, out of some mineral waters.

And to make it yet more probable, I could, in the ninth place, add divers experiments, by which several of these concretes may be in a short time made artificially by several chymical operations, which would very much illustrate the former doctrine. But I hope what I have mentioned may suffice to make the fourth proposition probable, that waters of divers kinds may be turned in time into stone, without being reducible again to water, by any art yet commonly known, which being granted, my

Fifth proposition will follow of consequence; namely, that divers other fluid substances, have, after long continuance of rest, settled and congealed into much more hard and permanent substances: for if water itself may be so changed and metamorphosed, which seems the farthest removed from the nature of a solid body, certainly those which are nearer to that nature, and are mixed with such waters, will more easily be coagulated. I shall not therefore any farther insist on the proof of this, than only to mention two particulars, and that because we have almost every where so many instances and experiments; the first is of *Pliny*^d in these words: *Verum et ipsius terræ sunt alia segmenta. Quis enim satis miretur, pessimam ejus partem, ideoque pulverem appellatam in Puteolanis collibus, opponi maris fluctibus, mergumque protinus fieri lapidem unum inexpugnabilem undis, et fortiore quotidie, utique si Cumano*

^d Lib. xxxv. cap. 13.

misceatur cæmento. Eadem est terræ natura in Cyzicena regione: sed ibi non pulvis, verum ipsa terra qualibet magnitudine excisa et demersa in mare, lapidea extrahitur. Hoc idem circa Cassandriam produnt fieri: et in fonte Gnidio dulci intra octo menses terram lapidescere. Ab Oropo quidem Aulidem usque quicquid terræ attingitur mari, mutatur in saxa, &c. To the end of the chapter he goes on to relate divers places where earths, &c. are turned into stones. And in another place^e he tells us, “*Nitrariæ egregiæ Ægyptijs: nam circa Naucratis et Memphim tantum solebant esse, circa Memphim deteriores: lapidescit ibi in acervis: multique sunt tumuli ea de causa saxei: faciunt ex his vasa, &c.*

The second is an observation of my own, which I have often taken notice of, and lately examined very diligently; which will much confirm these histories of *Pliny*, and this my present hypothesis; and that is a part of the observation which I made on the western shore of the Isle of *Wight*. I observed a cliff of a pretty height, which, by the constant washing of the water at the bottom of it, is continually, especially after frosts and great rains, foundering and tumbling down into the sea underneath it. Along the shore underneath this cliff, are a great number of rocks and large stones confusedly placed, some covered, others quite out of the water; all which rocks I found to be compounded of sand and clay, and shells, and such kind of stones as the shore was covered with. Examining the hardness of some that lay as far into the water, as the low-water-mark, I found them to be altogether as hard, if not much harder than

^e Lib. xxxi. cap. 10.

Portland or *Purbeck* stone. Others of them, that lay not so far into the sea, I found much softer, as having in probability not been so long expos'd to the vicissitudes of the tides: others of them I found so very soft, that I could easily with my foot crush them, and make impressions into them, and could thrust a walking stick I had in my hand, a great depth into them. Others that had been but newly founder'd down, were yet more soft, as having been scarce washed by the salt water: All these were perfectly of the same substance with the cliff, from whence they had manifestly tumbled, and consisted of layers of shells, sand, clay, gravel, earth, &c. and from all the circumstances I could examine, I do judge them to have been the parts of the neighbouring cliff tumbled down, and rowl'd and washed by degrees into the sea; and by the petrifying power of the salt water, converted into perfect hard compacted stones. I have likewise since observed the same phænomena on other shores: and I doubt not but any inquisitive naturalist may find infinite of the like instances all along the coast of *England*, and other countries where there are such kind of foundering cliffs. I shall not now mention the great quantities of toothed spar, which I observed to be crystallized upon the sides of these rocks, which seem'd to have been nothing else but the meer crystallizing or shooting of some kind of water, which was press'd or arose out of these coagulating stones: for the history of these kinds of figured stones belong more properly to another discourse; namely of the natural geometrical figures observable in ores, minerals, spars, &c. of which elsewhere.

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One instance more I cannot omit, as being the most observable of any I have yet heard of; and that is Dr. *Castle's* relation of a certain place at *Alpsly* in *Bedfordshire*, where there is a corner of a certain field, that doth perfectly turn wood and divers other substances in a very short time into stone, as hard as a flint or agate. A piece of this kind I saw, affirm'd to have been there buried, which the person that had buried it, had shot small shots of lead into. The whole substance of the wood, bark and pith, together with the leaden shot itself, was perfectly turned to a stone as hard as any agate, and yet retained its perfect shape and form; and the lead remained round, and in its place, but much harder than any iron.

But to spend no more time on the proof of that of which we have almost every where instances, divers of which I have already mentioned, I shall proceed to the sixth proposition; which is, that a great part of the surface of the earth hath been since the creation transformed, and made of another nature: that is, many parts which have been sea are now land, and others that have been land are now sea; many of the mountains have been vales, and the vales mountains, &c.

For the proving of which proposition I shall not need to produce any other arguments, besides the repeating what I find set down by divers natural historians concerning the prodigious effects that have been produced by earthquakes, on the superficial parts of the earth; because they seem to me to have been the chief efficient which have transported the petrified bodies, shells, woods, animal
sub-

substances, &c. and left them in some parts of the earth, as are no other ways likely to have been the places wherein such substances should be produced; they being usually either raised a great way above the level surface of the earth, on the tops of hills, or else buried a great way beneath that surface in the lower vallies: for who can imagine that oysters, muscles, periwinkles, and the like shell-fish should ever have had their habitation on the tops of the mountain *Caucasus*? Which is by divers of our geographers accounted as high in its perpendicular altitude, as any mountain in the yet known world; and yet *Olearius* affords us a very considerable history to this purpose, of his own observation, which I shall hereafter have occasion to relate, and examine more particularly. Or, to come a little nearer home, who would imagine that oysters, *Echini*, and some other shell-fish, should heretofore have lived at the top of the *Alpes*, *Apennine*, and *Pyrenean* mountains, all which abound with great store of several sorts of shells; nay, yet nearer, at the tops of some of the highest in *Cornwal* and *Devonshire*, where I have been informed by persons whose testimony I cannot in the least suspect, that they have taken up divers, and seen great quantities of them? And to come yet nearer, who can imagine oysters to have lived on the tops of some hills near *Banstead Downs* in *Surry*? Where there have been time out of mind, and are still to this day found divers shells of oysters, both on the uppermost surface of the earth, and buried likewise under the surface of the earth, as I was lately informed by several very worthy persons living near those

those places, and as I myself had the opportunity to observe and collect.

Of the Effects of EARTHQUAKES.

TO proceed then to the effects of earthquakes, we find in history four sorts or genus's to have been performed by them.

The first, is the raising of the superficial parts of the earth above their former level: and under this head there are four species. The first is the raising of a considerable part of a country, which before lay level with the sea, and making it lye many feet, nay, sometimes many fathoms above its former height. A second, is the raising of a considerable part of the bottom of the sea, and making it lye above the surface of the water, by which means divers islands have been generated and produced. A third species is the raising of very considerable mountains out of a plain and level country. And a fourth species is the raising of the parts of the earth, by the throwing on of a great access of new earth, and so burying the former surface under a covering of new earth many fathoms thick.

A second sort of effects performed by earthquakes, is the depression or sinking of the parts of the earth's surface below the former level. Under this head are also comprised four distinct species, which are directly contrary to the four last named.

The first, is a sucking of some part of the surface of the earth, lying a good way within the land,

and converting it into a lake of almost an unmeasurable depth.

The second, is the sinking of a considerable part of plain land, near the sea, below its former level, and so suffering the sea to come in, and overflow it, being laid lower than the surface of the next adjacent sea.

A third, is the sinking of the parts of the bottom of the sea much lower, and creating therein vast *vorages* and *abysses*.

A fourth, is the making bare, or uncovering of divers parts of the earth, which were before a good way below the surface; and this either by suddenly throwing away these upper parts, by some subterraneous motion, or else by washing them away by some kind of eruption of waters, from unusual places, vomited out by some earthquake.

A third sort of effects produced by earthquakes, are the subversions, conversions, and transpositions of the parts of the earth.

A fourth sort of effects, are liquefaction, baking, calcining, petrification, transformation, sublimation, distillation, &c.

The first therefore of the effects of earthquakes, which I but now named, was, that divers parts of the surface of the earth, which lay below, or level with the sea, have been raised a good height above that level, by earthquakes. Of this *Pliny* gives us several instances. ^f *Eadem nascentium causa terrarum est, cum idem ille spiritus attollendo potens solo non valuit erumpere. Nascuntur enim nec fluminum tantum in vectu, sicut Echinades insulæ ab Acheloo*

^f Hist. nat. lib. ii. cap. 85.

amne congestæ; majorque pars Ægypti a Nilo, in quam a Pharo insula noctis et diei cursum fuisse Homero credimus: sed et recessu maris sicut eidem Circeis. Quod accidisse et in Ambraciæ portu decem millium passuum intervallo, et Atheniensium quinque millium ad Piræum memoratur: et Ephesi, ubi quondam ædem Dianæ alluebat. Herodoto quidem si credimus, mare fuit supra Memphim usque ad Æthiopum montes: itemque a planis Arabiæ. Mare et circa Ilium, et tota Teuthrania, quaque campos intulerit Mæander.

And Sandys also, in his travels through *Italy*, and the parts of the *Levant*, gives this instance^g, speaking of the new mountain, which was produced in the kingdom of *Naples*, in the year 1538, says,
 “ The lake *Lucrinus* extended formerly to *Avernus*,
 “ and so unto *Gaurus*, two other lakes; but is now
 “ no other than a little sedgy plash, choaked up
 “ by the horrible and astonishing eruption of a new
 “ mountain, whereof, as oft as I think, I am apt
 “ to credit whatsoever is wonderful. For who in
 “ *Italy* knows not, or who elsewhere will believe,
 “ that a mountain should arise, partly out of a
 “ lake, and partly out of the sea in one day and
 “ a night, to such a height, as to contend in altitude with the high mountains adjoining!

“ In the year of our Lord 1538 on the 29th of
 “ *September*, when for certain days foregoing, the
 “ country thereabouts was so vext with perpetual
 “ earthquakes, as no one house was left so intire, as
 “ not to expect immediate ruin, after that the sea
 “ had retired 200 paces from the shore, leaving
 “ abundance of fish, with springs of fresh water

^g P. 277.

“ rising

“ rising at the bottom, this mountain visibly ascended about the second hour of the night, &c.” And again ^h, speaking of the same place, “ The sea was accustomed, when urged with storms, to flow in through the lake *Lucrinus*, driving fishes in with it; but now, not only that passage, but a part of *Avernus* itself is choak’d up by the mountain.”

In which histories I take notice only of these two particulars at present. First, that that part of the land which lies between *Lucrinus* and the sea, that was oft-times before overflowed by the sea; since this earthquake has been so far raised, as that now such effects are no longer to be found. To confirm the rising of which the more, the other circumstance of the sea’s departing from the shore 200 paces does much contribute. But, not to insist on this, Mr. *Childrey*, in his *Britannia Baconica*, a book very useful in its kind, being a collection of all the natural history of the islands of *Great Britain*, to be met with in *Cambden* or *Speed*, and some other historians, together with such of his own as he had opportunity to observe, relates to us many considerable passages to this purpose. In his history of *Norfolk*, he says, “ that near *St. Benet’s* in the *Holm*, are perfect cockles and periwinkles sometimes digged up out of the earth, which makes some think it was formerly overflowed by the sea.” The fenny grounds also of *Lincolnshire* and *Cheshire*, seem to have proceeded from the rising of the ground; and those in *Anglesey*, where lopp’d trees are now digged up with

^h Page 281.

the perfect strokes of the ax remaining on them, seem to have been first sunk under water, then overturned and buried in their own earth, and afterwards the whole earth seems to have been raised again to its former height.

Linschoten gives us a relation of the like effects that happened in the *Tercera's*. The relation, as I find it epitomiz'd by *Purchas*ⁱ is this: "In *July*
 " *anno* 1591, there happened an earthquake in the
 " island of *St. Michael*, which lieth from *Tercera*
 " south about 28 miles, an island 20 miles long,
 " and full of towns, which continued from *July*
 " 26 to *August* 12, in which time none durst stay
 " within his house, but fled into the fields, fasting
 " and praying with great sorrow, for that many
 " of their houses fell down, and a town called
 " *Villa Franca*, was almost razed to the ground,
 " all the cloysters and houses shaken to the earth,
 " and therein people slain. *The land in some places*
 " *rose up*, and the cliffs removed from one place
 " to another, and some hills were defaced and
 " made even with the ground. The earthquake
 " was so strong, that the ships which lay in the
 " road, and in the sea, shaken as if the world
 " would have turned round. There sprung also
 " a fountain out of the earth, from whence, for
 " the space of four days, there flowed a most clear
 " water, and after that it ceased. At the same time
 " they heard such thunder and noise under the
 " earth, as if all the devils had been assembled
 " together at that place, wherewith many died for
 " fear. The island of *Tercera* shook four times

ⁱ *Pilgrim.* part. iv. p. 1677.

“ together, so that it seemed to turn about; but
 “ there happened no other misfortune unto it.
 “ Earthquakes are common in those islands: for
 “ about 20 years past there happened another
 “ earthquake, when a high hill that lieth by the
 “ same town *Villa Franca*, fell half down, and co-
 “ vered all the town with earth, and killed many
 “ men.” I have transcribed here, once for all,
 the whole relation, because there are many other
 considerable circumstances in it besides the rising
 of the earth, which I shall have occasion to refer
 to, under others of the heads or propositions to be
 proved, and therefore shall not need repetition.
 Two other relations I find collected by *Purchas*,
 confirming this, and several of the other proposi-
 tions: the one is that of *Dithmar Blefken* in the his-
 tory of *Island*^k. “ On the 29th of *November* a-
 “ bout midnight, in the sea, there appeared a
 “ flame near *Hecla*, which gave light to the whole
 “ island: an hour after the whole island trembled,
 “ as it would have been moved out of the place:
 “ after the earthquake followed a horrible crack,
 “ that if all war-like ordnance had been discharg-
 “ ed, it had been nothing to this terror. It was
 “ known afterwards that *the sea went back two*
 “ *leagues in that place, which remained dry.*”

A second history *Purchas* has collected out of
 the history of *Joseph Acosta* of the *West Indies*^l; o-
 mitting for the present divers other circumstances
 he takes notice of, I shall only mention that of the
 receding of the sea.” “ Upon the coast of *Chili*, I
 “ remember not well in what year, there was so ter-

^k *Id.* part iii. p. 648.

^l Part iii. p. 940.

“ rible an earthquake, as it overturned whole
 “ mountains, and thereby stopt the course of ri-
 “ vers, which it converted into lakes. It beat
 “ down towns, and slew a great number of peo-
 “ ple, causing the sea to leave her place some
 “ leagues, so as the ships remained on dry ground,
 “ far from the ordinary road, &c.” An example
 somewhat like this happen’d lately in the *East In-*
dies, as I was lately informed by a letter from
 thence. The thing in short was this: at a place
 about seven days journey from *Ducca*, the earth
 trembled about 32 days; and the sequel was, that
 it raised the bottom of a lake, so as to drive out
 all the water and fish upon the land, so that a place
 which was formerly a lake is now dry ground.
 This was written from *Ballasore*, Jan. 6, 1665.

The second species of effects of earthquakes, is
 the raising a considerable part of the bottom of the
 sea, and making it lie above the surface of the wa-
 ter, by which means several islands have been ge-
 nerated. Of this *Pliny* gives us several instances^m.
Nascuntur et alio modo terræ (having in the preced-
 ing chapter spoken of the shores rising above the
 water, or the waters deceding from the shore) *ac*
repente in aliquo mari emergunt, veluti paria secum
faciente natura, quæque hausserit hiatus, alio loco red-
dente. Claræ jampridem insulæ, Delos et Rhodos,
memoriæ produnt enatæ. Postea minores, ultra Melon
Anaphe (of which *Strabo* makes mentionⁿ.) *Inter*
Lemnum et Hellespontem Nea. Inter Lebedum et Teon,
Alone: inter Cycladas, Olympiadis cxxxv. anno 4^{to}, The-
ra et Therasia. Inter easdem post ann. cxxx Hiera:

^m Lib. ii. cap. 86, 87.

ⁿ Lib. x.

et ab ea duobus stadijs post ann. cx in nostro ævo, M. Junio Syllano, L. Balbo COSS. ad VIII Idus Julias, Thia. Two of which histories are also confirmed by *Seneca* °, where explicating the effects of earthquakes by the commixture of fire and water, he says, *Theren et Therasiam et hanc nostræ ætatis insulam, spectantibus nobis in Ægæo mari enatam quis dubitat quin in lucem spiritus vexerit.* *Sandys* speaking of the *Iolian* islands, saith, “ Of those there were only seven, now there are eleven in number, which heretofore all flamed; now only *Vulcano* and *Strombylo*, two of that number, do burn.” *Vulcano* is said first of all to have appeared above water about the time that *Scipio Africanus* died. But we have much later instances to confirm this our assertion: for about 28 years since, an island was made among the *Azores* by an eruption of fire, of which divers have related the story. But *Kircher* p, from the relation of the Jesuits, has added the most particular one. Having spoken of the exceeding height of the *Pike* of *Teneriffe* in the *Canaries*, and of the eruptions of fire in it, and the hot springs round about it, he adds, that in the *Azores* also there are found places having almost the same properties. The *Pico de Fayal de Santo Gregorio*, being almost of equal height, and *St. Michael's* island having had heretofore several *Vulcans*, and having been troubled with many earthquakes, and very notably about 38 years since, wherein all the island was so terribly shaken, that the utter ruin and subversion of the whole was feared. The history of which, in short, is this; that “ *June*

° Quæst. nat. lib. vi.

p Mund. subterr.

“ 26, 1638, the whole island began to be shaken
“ with earthquakes for eight days, so that the in-
“ habitants left cities, castles and houses, and dwelt
“ in the fields, but especially those of a place call-
“ ed *Vargen*, where the motion was more violent.
“ After which earthquake this prodigy followed.
“ At a place of the sea, where fishermen used to
“ fish in summer, because of the great abundance
“ of fish there caught, called *La Femera*, about
“ six miles from *Pico Delle Carmerine*, upon the first
“ funday in *July*, a subterraneous fire, notwith-
“ standing the weight and depth of the sea in that
“ place, which was 120 foot, as the fishermen had
“ often before that found by sounding, and the
“ multitude of waters, which one would have
“ thought sufficient to have quenched the fire: a
“ subterraneous fire, I say, broke out with a most
“ inexpressible violence, carrying up into the clouds
“ with it water, sand, earth, stones, and other
“ vast bulks of bodies; which to the sad specta-
“ tors, at a distance, appeared like flocks of wool
“ or cotton, and falling back on the surface of
“ the water, look'd like froth. The space of this
“ eruption was about as big as a space of land,
“ that might well be sown by two bushels of grain.
“ By great providence the wind blew from the
“ land; otherwise the whole island would, in all
“ probability, have perished by the merciless rage
“ of these devouring flames. Such vast bulks of
“ stone were thrown up into the air, about the height,
“ to seeming, of three pikes length, that one would
“ rather think them mountains than rocks: and
“ which added further to this dreadful sight, was,
“ that

“ that these mountains returning again, often met
 “ with others ascending or being thrown up, and
 “ were thereby dasht into a thousand pieces ; di-
 “ vers of which pieces being afterwards taken up
 “ and bruised, easily turned into a black shining
 “ sand. Out of the great multitude and variety
 “ of these vast rejected bodies, and the immense
 “ heaps of rocks and stones, after a while was
 “ formed a new island out of the main ocean,
 “ which at first was not above five furlongs over;
 “ but after a while, by daily accessses of new mat-
 “ ter, it increased after fourteen days to an island
 “ of five miles over. From this eruption, so great
 “ a quantity of fish was destroyed and thrown up-
 “ on the next adjacent island, that eight of the
 “ biggest *Indian* galeons would not be sufficient to
 “ contain them ; which the inhabitants fearing,
 “ lest the stink of them might create a plague, for
 “ eighteen miles round collected and buried in
 “ deep pits. The stink of the brimstone was
 “ plainly smelt at 24 miles distance.” But we
 have an instance more of the generation of an is-
 land out of the bottom of the sea, by an eruption ;
 which because it happened very lately, namely in
 1650, and near an island in the *Archipelago*, which
Pliny relates to have been heretofore after the same
 manner produc’d, I shall in short relate, as it is
 more largely recorded by *Kircher* ^a from the mouth
 of Father *Franciscus Riccardus*, a Jesuit, who was
 at the same time in the adjoining island, and an
 eye witness of all the phænomena.

^a Mund. subterr.

“ From the 24th of *September* to the 9th of *October* 1650, the island of *Santerinum*, formerly
“ called by *Pliny*, *Tbera*, was dreadfully shaken
“ with earthquakes, so that the inhabitants expected
“ nothing but utter ruin; and were yet more
“ amazed by a horrid eruption of fire out of the
“ bottom of the sea, about four miles to the east-
“ ward of the island: before which the water of
“ the place was raised above 30 cubits perpendi-
“ cularly. (I suppose he means as to appearance
“ from the island, otherwise 'tis but very little)
“ which wave spreading itself round every way,
“ overturned every thing it met, destroying ships
“ and galleys in the harbour of *Candie*, which was
“ 80 miles distant. The eruption filled the air
“ with ashes and horrible sulphureous stinks, and
“ dreadful lightnings and thunder succeeded. All
“ things in the island were covered with a yellow
“ sulphureous crust, and the people almost blind-
“ ed as well as choaked. Multitudes of pumice
“ and other stones were thrown up, and carried
“ as far as *Constantinople*, and to places at a very
“ great distance. The force of this eruption was
“ greatest the two first months, when all the
“ neighbouring sea seemed to boil, and the *Vul-*
“ *can* continually vomited up fire balls. Upon
“ the turning of the wind, great mischief was
“ done in the island of *Santerinum*; many beasts
“ and birds were killed: and on the 29th of *Octo-*
“ *ber* and the 4th of *November*, about 50 men
“ were killed by it. The other four months it
“ lasted, tho' much abated of its former fierce-
“ ness, yet it still cast up stone, and seemed to en-
deavour

“ deavour the making of a new island ; which tho’
 “ it do not yet perfectly appear above water, yet
 “ ’tis covered but eight foot by the water ; and the
 “ bubbling of the water seems to bespeak another
 “ eruption, that may in time finish natures birth.”

And though our natural historians have been very scarce in the world, and consequently such histories are very few ; yet there has been no age wherein such historians have lived, but has afforded them an example of such effects of earthquakes. And I doubt not, but had the world been always furnished with such historians as had been inquisitive and knowing, we should have found not only *Thera* or *Santerinum*, and *Vulcano*, and *Delos*, and that in the *Azores*, and one lately in the *Canaries*, but a very great part of the islands of the whole world, to have been raised out of the sea, or separated from the land, by earthquakes : for which opinion I shall afterwards relate several observations both of my own and others, which seem to afford probable arguments.

But to proceed to the third kind or species of effects produced by earthquakes, which is the raising very considerable mountains out of plains. Of this I shall add a few instances ; but none more notable, than that of the new mountain near *Naples*, of which I said somewhat before out of *Sandys’s* travels. In the year 1538, *Sept.* 29th, this mountain visibly ascended about the second hour of the night, with a hideous roaring, horribly vomiting stones, and such store of cinders as overwhelmed all the buildings thereabouts, and the fabulous baths of *Tripergula*, for so many ages celebrated,

celebrated, consuming all the vines to ashes, and killing birds and beasts, and frightening away all the inhabitants, who fled naked and defiled through the dark: and has advanced its top a mile above the basis: the stones of it are so light and porey that they will not sink when thrown into the sea. This new mountain, when new raised, had a number of issues, some of them smoking, some flaming, others disgorging rivulets of hot water, keeping within a terrible rumbling; and many perished that ventur'd into the hollowness above. But that hollow on the top is at present an orchard, and the mountain throughout bereft of its terrors. “It is reported, says *Childrey*^r, that by the sea side, not far from *Axbridge* in *Somersetshire*, within these 50 years, a parcel of land swell'd up like a hill, but on a sudden clave asunder, and fell down into the earth; and in the place of it remains a great pool.” Our *English* chronicles say, at *Oxenhal*, in the bishoprick of *Durham*, on *Christmas* day 1179, the ground heav'd up aloft like a tower, and continued all the day unmovable, till evening, and then fell with a horrible noise, sinking into the earth, and leaving three deep pits called hell-kettles. *Vorenus*^f tells us of a new mountain likewise raised in *Java*, in the year 1586, with the like effects of those I formerly named of the new mountain; first shaking the earth, then heaving up, and throwing up into the air, the upper parts of the earth, afterwards the rock and inner parts, then fiery coals and cinders, overwhelming the circumjacent fields and towns, and killing above

^r Britan Baconic.

^f Geogr.

10,000 men, and burning what was not overwhelmed. I have not time to reckon up the multitude of instances I have met with in authors; such as *Ætna* in *Sicily*, *Vesuvius* in *Italy*, one in *Croatia*, near the city *Valonia*, the *Pike* in *Teneriffe*, and the *Pike* in the *Azores*, *Hecla*, *Helga*, and another in *Island*: the mount *Gonnapi* in one of the islands of *Banda*, which made an horrid eruption at the same time with that in *Java*. The mount *Balavane* in *Sumatra*: others in the *Molucca* islands, in *China*, *Japan*, and the *Philippines*, and in some of the *Maurician* islands, and several other parts of the *East Indies*. In the *West Indies* also we have multitudes of examples; several in *Nicaragua*, and all along the ledge of mountains in *Peru* and *Chili*, and in *New Spain* and *Mexico*: in the islands of *Papoyo*s, discovered by *La Mair* joining to the south continent in *Mar Del Zur*: all which are so many shining torches to direct us in the search after this truth. There are many other instances of mountains, that have but lately, as it were, left to burn, and are covered with wood and grown fruitful. So the new mountain I formerly mentioned, has an orchard growing where the fire at first flamed. Another in the island *Quimada*, near the river *Plata* in *Brasil*: the islands also of *St. Helena*, and *Ascension*, discovered by the great plenty of cinders, and the fashions of the hills, to have formerly contained *Vulcanos*, and probably were at first made by some subterraneous eruption, as indeed most of those islands in the main ocean, such as the *Canaries*, and the *Azores*, and the *East Indian*, and the *Caribbee* islands, and divers others seem to have been,

been. A passage to make this assertion somewhat the more probable, I have met with in *Linschoten's* description of the isle of *Tercera*, which, as *Purchas* has epitomized^t, I have here added. “The land
 “ is very high, and, as it seemeth, hollow; for
 “ that as they pass over an hill or stone, the ground
 “ foundeth under them as if it were a cellar: so
 “ that it seems in divers places to have holes under the earth, whereby it is much subject to
 “ earthquakes, as also all the other islands are;
 “ for there it is a common thing: and all those
 “ islands, for the most part, have had mines of
 “ brimstone; for that in many places of *Tercera*
 “ and *St. Michael*, the smoke and favour of brimstone doth still issue out of the ground, and the
 “ country round about is all singed and burnt.
 “ Also there are places wherein there are wells,
 “ the water whereof is so hot that it will boil an
 “ egg, as if it were over a fire.” Besides which, the shape of the hills, and several other circumstances mentioned by *Linschoten*, do make it probable that those have been all *Vulcano's*.

But to proceed to the fourth species of the effects of earthquakes under this head; and that is, the raising of the parts of the earth, by the throwing on a great access of new earth: of this I have already given many instances in the newly mentioned histories of eruptions, where I mentioned the overwhelming of fields, towns and woods. I shall only add one instance or two more to confirm this head, and then proceed. The first is that mentioned by *Olaus Wormius*^u, where he gives an ac-

^t Pilgr. part iv. p. 1670. ^u Musæi. lib. i. sect. i. chap. 5.

count of an extraordinary earthquake in *Iceland*, which filled the air with dust, earth, and cinders, and overwhelmed towns, fields, and even ships a good way distant at sea; and which sent forth its fumes with such violence and plenty, as covered all the decks and sails of ships lying on the coast of *Norway*, some hundred leagues distant. And to make this of *Wormius* the more probable, I have now by me a paper of dust, which was rained out of the air upon a ship lying at *Algier* upon the coast of *Barbary*, upon a great eruption of *Vesuvius* in the year 1600. But what is beyond all, is the late eruption of *Mongibell* or *Ætna*.

And to confirm this proposition yet further, I cannot pass by a very remarkable rain of earth and ashes, that happened in *Peru*, anno 1600, mentioned by *Garcelasso de la Vega*, one of the offspring of the *Inca's* of *Peru*, in his history of *America*. The epitome of which by *Purchas*^w, is this. “I might
 “ add the great earthquakes anno 1600 in *Peru* at
 “ *Arequipa*, the raining of sand, as also of ashes a-
 “ bout 20 days from a *Vulcano* breaking forth;
 “ the ashes falling in places above a yard thick,
 “ in some places more than two, and where least,
 “ above a quarter of a yard, which buried the corn
 “ grounds of maize and wheat, and the boughs
 “ of trees were broken and fruitless, and the cat-
 “ tle great and small died for want of pasture: for
 “ the sand which rained covered the fields thirty
 “ leagues one way, and above forty leagues ano-
 “ ther way. Round about *Arequipa* they found
 “ their kine dead by 500 together in several herds,

^w Pilg. part iv. p. 1476.

“ and

“ and whole flocks of sheep, and herds of goats
 “ and swine buried. Houses fell with the weight
 “ of the sand, and others cost much industry to
 “ save them. Mighty thunders and lightning
 “ were heard and seen 30 leagues about *Arequipa*.
 “ It was so dark whilst those showers lasted, that
 “ at mid-day they burned candles to see to do
 “ business.”—I could add divers other instances
 to confirm this proposition, but these may at present suffice.

But this is but one way by which divers things have been buried: there is another way which I can only at present mention, and must refer the probation and prosecution to some other occasion; and that is, that very many of the lower superficial parts of the earth, have been, and are continually covered and buried by the access of matter, tumbled and washed down by excesses of wind and rain, and by the continual sweepings of rivers, and streams of water. Under this head I shall shew several places and countries in the world, that are nothing else but the productions of these causes. To this purpose *Peter de la Valle* ^x gives some observations which he made in *Egypt*, “ Of the former seven
 “ mouths of *Nile*, there are only four left, and of
 “ those but two navigable; the rest are either filled, or run no more, or are small streams not
 “ taken notice of, or only torrents in the time of
 “ great rains: but I could learn nothing of them,
 “ because the great expence of the ancients for
 “ cleansing the ditches, has been intermitted for
 “ several hundreds of years.” He is likewise of

^x Letter xith dated from *Grand Cairo*, Jan. 25, 1616.

opinion, with *Herodotus*, that the *Delta*, and all the lower *Egypt*, where the *Greeks* navigated in his time, was in the first ages of the world made by the sand and mud of *Nile*.

All which histories and particulars do manifestly enough evince, that there have been in very many parts of the world considerable mutations of the superficial parts, since the beginning; and that therefore those places where these petrified bodies are found, though they now seem never so much foreign, and differing from the likely native places of such animated bodies, may notwithstanding heretofore have been in such another kind of condition, as was most suitable to the breeding and nourishment of them, which I shall yet further manifest, by comparing the other effects produced by earthquakes; such as the sinking, and burying, and transposing, and overturning of the superficial parts of the earth.

Another sort of effects, is the sinking of the superficial parts of the earth, and placing them below their former position, both in respect of some parts newly raised, and in respect of some other adjacent parts not displaced. And this seems to be caused by the subsiding or sinking those parts into such caverns, as by the strength of the eruption passing below, before it breaks out, are made underneath. And if the parts of the earth underneath are so loose or obnoxious to the force of the fire, as to be dislodged; unless the remaining parts be very strong, and constitute a very firm stony arch, the earth does very easily tumble into the holes and hollows made by the fire. Now it cannot be imagined

gined but that all those vast congeries of earth, which I have already mentioned to have been thrown up, and to create new islands and new mountains, and the like, must leave vast caverns below them, to be filled, either with the parts of the earth that hang immediately over them, or with the sea, or other subterraneous waters, if the roofs of these cavities be strong enough to sustain the earth above them from sinking. And some such power as these subterraneous fires, seems to me to have been the cause of the strange positions and intermixture of the veins of ores and minerals in the bowels of the mountains, where, for the most part, they are now found; and even of bringing those substances so near the surface of the earth, which from the consideration of very many circumstances, seem to me to be naturally situated at a much greater depth below within the bowels of this globe. And hence may be rendred a reason of the figures of those minerals, and other of those substances mixed with them, and of the compounding and blending of several of these substances together, whereby some of them are very strangely united and alter'd. But this I mention only by the by, and shall not insist on it, belonging more properly to another head. To proceed then, under this general head are comprised several kinds of effects, differing only according to the parts of the earth they have been wrought upon.

The first is, the sinking of several inland parts, which were before eminent, and laying them much lower into vales. Sometimes, the sinking of a part of the earth to a very great depth, and leaving

ing behind, instead of a firm ground, a lake of salt or sea-water. Of these we have several instances in natural historians. And, to pass by many others, I shall only mention such as have lately happened. Of this kind Mr. *Childrey* in his *Britannia Baconica*, has collected several instances, two out of our *English* chronicles: his relations are these^y. “August the 4th, 1585, after a very violent storm of thunder and rain, at *Mottingham* in *Kent*, eight miles from *London*, the ground suddenly began to sink; and three great elms growing upon it, were carried so deep into the earth, that no part of them could any more be seen. The hole left (saith the story) is in compass 80 yards about, and a line of 50 fathoms, plumm’d into it finds no bottom.” Also, “December 18, 1596, a mile and half from *Westram* southward (which is not many miles from *Mottingham*) a part of an hedge of ashes, 12 perches long, was sunk six foot and an half deep; the next morning 15 foot more; and the third morning 80 foot more at least, and so daily.” (And presently afterwards he says) “Moreover in one part of the plain field there is a great hole made by sinking of the earth, to the depth of 30 foot at least, being in breadth in some places, two perches over, and in length five or six perches. There are sundry other sinkings in divers other places; one of 60 foot, another of 47, and another 34 foot; by means of which confusion it is come to pass, that where the highest hills

^y Page 62.

“ were, there be the lowest dales, and the lowest
 “ dales are become the highest grounds, &c.”

And again^z, he gives an instance upon his own knowledge, much to the same purpose, which lately happened. “ *July* the 8th 1657, about three
 “ of the clock, in the parish of *Bickly*, was heard
 “ a very great noise like thunder afar off; which
 “ was much wondered at, because the sky was
 “ clear, and no appearance of a cloud. Shortly
 “ after (saith the author of this relation) a neighbour came to me, and told me, I should see a
 “ very strange thing if I would go with him. So
 “ coming into a field, called the *Lay-Field*, we
 “ found a very great bank of earth, which had
 “ many tall oaks growing on it, quite sunk into
 “ the ground, trees and all. At first we durst
 “ not go near it, because the earth, for near 20
 “ yards about, was exceedingly much rent, and
 “ seemed ready to fall: but since that time myself
 “ and some others have ventur’d to see the bottom, I mean to go to the brink, so as to discern
 “ the visible bottom, which is water, and conceived to be about 30 yards from us; under
 “ which is sunk all the earth about it, for 16 yards
 “ round at least, three tall oaks, a very tall awber,
 “ and certain other small trees, and not a sprig of
 “ them to be seen above water. Four or five oaks
 “ more are expected to fall every moment, and
 “ a great quantity of land is like to fall, indeed
 “ never ceasing more or less; and when any considerable clod falls, it is much like the report
 “ of a cannon. We can discern the ground hol-

“ low above the water a great depth; but how far
 “ hollow, or how deep, is not to be found out by
 “ man. Some of the water (as I have been told)
 “ drawn out of this pit with a bucket, was found
 “ to be as salt as sea water, &c.”

“ A considerable circumstance also to confirm this proposition, is a passage in that history I have mentioned out of *Linschoten*, of the island of *Ter-cera*, where he says, *and some of the hills were defaced and made even with the ground.*

Kircher tells us a very remarkable history of the sinking of a town, and the land about it, and the generation of a lake instead of it^a. *Contigit hac eadem horâ res æternâ ac immortalî memoriâ digna, &c.* “ At this very time happened a thing worthy never to be forgotten, to wit the subversion of the most famous town called *St. Euphemia*: ’twas situated at the side of the bay under the jurisdiction of the knights of *Malta*. When therefore we had come to *Lopiz*, almost dead from the violent shaking of the earth, and lying prostrate on the ground, at last the *Paroxysm* of nature remitting, casting our eyes towards the neighbouring places, we saw the forementioned town encompassed with a great, wonderful, and unusual cloud, which was seen by us three times, especially at three o’clock in the afternoon, the heavens being clear. This cloud being by degrees dissipated, we look’d for the town, but found it not; a stinking lake, to our wonder, appearing in the place of it. We sought for some person or other, to give us some certain account of this unusual event; but could not

^a Mund. subterr. præfat. cap. 2.

“ find one to tell any news of this dreadful acci-
 “ dent and great destruction, &c. We prosecuting
 “ our journey, and passing by *Nicastro*, *Amantea*,
 “ *Paula*, *Belvedere*, found nothing for 200 miles,
 “ but the remaining carcasses of cities and castles,
 “ and horrid destructions ; the men lying in the
 “ open fields, and, as it were, dead and withered
 “ through fear and terror.”

To this purpose give me leave to subjoin an ex-
 tract of a letter, sent from *Balafore* in the *East In-*
dies, Jan. 6, 1665. “ The same star appeared in
 “ our horizon about the same time ’twas seen with
 “ you. The effects have in part been felt here
 “ by unseasonable weather, great mortalities a-
 “ mong the natives, *English*, and others. We have
 “ had several earthquakes, unusual here, which with
 “ hideous noises, have in several places broke out,
 “ and swallowed up houses and towns. But about
 “ seven days journey from *Ducca*, where were at
 “ that time three or four *Dutch*, they and the na-
 “ tives relate, that in the market place, the earth
 “ trembled about 32 days and nights, without in-
 “ termission. At the latter end, in the market
 “ place, the ground turned round as dust in a
 “ whirlwind, and so continued several days and
 “ nights, and swallowed up several men who were
 “ spectators, who sunk and turned round with the
 “ earth, as in a quagmire. At last the earth
 “ worked and cast up a great fish, bigger than
 “ hath been seen in this country, which the peo-
 “ ple caught : but the conclusion of all was, that
 “ the earth sunk with 300 houses, and all the men,
 “ where now appears a large lake some fathoms
 “ deep.

“ deep. About a mile from this town was a lake
 “ full of fish, which in these 32 days of the earth-
 “ quake cast up all her fish on dry land, where
 “ might have been gathered many, which had
 “ run out of the water upon dry land, and there
 “ died: but when the other great lake appeared,
 “ this former dried up, and is now firm land.”

To the same purpose also we have several o-
 ther instances, some later, and some nearer home.
 “ Near *Darlington*, (says *Childrey*^b, speaking of
 “ the rarities of the bishoprick of *Durham*) are
 “ three pits, whose waters are warm, (hot says
 “ *Cambden*) wonderful deep, called hell-kettles.
 “ These are thought to come of an earthquake,
 “ that happened *anno* 1179. For on *Christmas*
 “ day, say our chronicles, at *Oxenball*, which is
 “ this place, the ground heaved up aloft like a
 “ tower, and so continued all that day, as it were
 “ immoveable, till evening, and then fell in with a
 “ very horrible noise, and the earth swallow’d it up,
 “ and made in the same place three deep pits.”
 The same, in the section of *Brecknock*, says, “ Two
 “ miles east of *Brecknock*, is a meer, called *Llin-*
 “ *savathan*, which, as the people dwelling there
 “ say, was once a city; but the city was swallow-
 “ ed up by an earthquake, and this water or lake
 “ succeeded in the place; the lake is encompassed
 “ with steep high hills, &c.”

“ Near *Falkirk*, says *Lithgow*, remain the ruins
 “ and marks of a town, &c. swallow’d up into
 “ the earth by an earthquake, and the void place
 “ is filled with water.” *Pliny* also records a like

^b Præfat. Mund. subterr. cap. 2.

instance^c, *Mox in his montem Epopon, &c.* “ Presently the mountain *Epopon* (when suddenly a flame had shone out of it) was levell’d with the plain, and in the same plain a town was swallowed up into the deep, and by another motion of the earth became a lake. And in another place the mountain being tumbled down, the island *Prochyta* arose, &c.”

The *Dead Sea* also in *Palestine*, was the production of a most terrible earthquake, and a fire sent from heaven. For, methinks, the relation of the sad catastrophe of those four cities, *Sodom, Gomorrah, Zeboim, Adma*, mentioned in scripture, seem somewhat like that I have newly related out of *Kircher* of *St. Euphemia*. There are a multitude of other instances which I could bring on this head, of the sinking of mountains and hills into plains, and all these into lakes, of which *Pliny* gives several instances^d. The *Pico* in the *Molucca’s*, accounted of equal height with that of *Teneriffe*, was, by a late earthquake, quite swallowed into the earth, and left a lake in its place. *Vesuvius* and *Strongylus*, are by late earthquakes reduced to almost half their former height. Many of those vast mountains of the *Andes* in *Chili*, were by an earthquake *ann. 1646*, quite swallowed up and lost, as *Kircher* relates. I could add many histories of the fatal catastrophe’s of many towns, and other places of note; but these, I hope, may suffice to shew this kind also of mutation in the superficial parts of the earth, to be effected by earthquakes.

^c *Britann. Baconic.*

^d *Hist. nat. lib. ii. cap. 88.*

Nor do earthquakes only sink mountains and inland parts; but such parts also as are near to, equal with, and under the surface of the sea. Of this we have instances near home, of *Winchelsea* and of the *Goodwin Lands*, and of the towns in *Freezland*, that have been about 400 years since swallowed up by the sea; and nothing but towers and the *Goodwin Sands*, are now to be found of them. The like happened to several parts of *Scotland*, as *Heſtor Boethius* relates. *Linschoten*, in his history of the *West Indies*, relates, among many other histories this considerable passage. “ Since, “ in the year 1586, in the month of *July*, fell “ another earthquake in the city of *Kings*, the “ which, as the vice-roy did write, had run 170 “ leagues along the coast, and athwart to the *Sierra* “ 50 leagues. It ruined a great part of the city. “ It caus’d the like trouble and motion of the “ sea, as it had done at *Cbili*, which happened “ presently after the earthquake; so as they might “ see the sea to fly furiously out of her bounds, and “ to run near two leagues into the land, rising above fourteen fathom. It covered all the plain, “ so as the ditches were filled, and pieces of wood “ that were here, swam in the water.” There are multitudes of instances of the like effects in several other parts of the world, which have been wrought by earthquakes, which may be found in natural historians; which, for brevity’s sake, I omit, they serving only to prove a proposition, which I suppose will be granted by any that have either seen or heard of the effects of earthquakes.

Now, though I find a general deficiency in natural historians, of instances to prove, that the submarine parts have likewise suffered the like effects of sinking; they lying out of view, and so cannot without some trouble and diligence be observed; yet if we consider from how great a depth these eruptions proceed, and how little distinction they make between mountains and plains, as to the weight of removing, we may easily believe, that the bottom of the sea is as subject to these mutations, as the parts of the land. And since, by the former relations, we have many instances of the raising of the bottom of the sea, 'tis very probable, that what quantity of matter is thrown to and raised in one place, is sunk, and falls into that cavity left by another. An island cannot be raised in one place, without leaving an abyss in another. And I do not doubt, but there have been as many earthquakes in the parts of the earth under the ocean, as there have been in the parts of the dry land: but being for the most part till of late, unfrequented by mankind, and even now but very thinly, 'tis almost a thousand to one, that what happen are never seen; and a hundred to one, if they have been seen, whether they be recorded: for how few writers are there of natural history?—There is somewhat of probability in the story related by *Plato*, in his *Timæus*, of the island *Atlantis*, in the *Atlantic* ocean, which, he says, was swallowed up by an earthquake, into the sea. And 'tis not unlikely, but that most of those islands that are now appearing, have been either thrown up out of the sea by eruptions, such as the *Canaries*, *Azores*,

res, *St. Helena*, &c. which the form of them, and the *Vulcano's* in them, and the cinders and pumice stones found about them, and the frequent earthquakes they are troubled with, and the remaining hills of extinguished *Vulcano's*, do all strongly argue for: or else, that they are, some of them at least, some relicks of that great island which is now not to be found; and yet we have no records hereof. That there is as great inequality in the depth of the sea, as there is in the height of the land, the observations of seamen, experimented by their sounding-lines, do sufficiently inform us: for hills, we have deep holes; and for mountains and pikes, abysses and malstrooms: and that these must have, in all ages, been filling with parts of the earth, tumbled by the motion of the waters, and rowling to the lowest place, is very probable; and so they would in time have been filled up, had not earthquakes, by their eruptions and tumblings, created new irregularities. And therefore that there are still such places, is an argument, that there have been of later ages earthquakes in some of them. Of these I shall mention one or two instances, which I meet with in voyages, and the relations of travellers.

In the relation of the circumnavigation of Sir *Francis Drake*, speaking of the straights of *Magellane*, he says, page 35, "They saw an island with a very high *Vulcano*;" and the next page he says, "They had need to have carried nothing but anchors and cables, to find ground, the sea was so very deep;" which depth is explained more expressly page 42, where it is said, "Being driven
" from

“ from our first place of anchoring, so unmeasurable was the depth that 500 fathom would fetch no ground.” And in page 99, of the same relation, the author tells, how their ship struck upon a rock, which, page 102, he says “ At low water was but six foot under water, and just by it no bottom to be found, by reason of the great depth.”

Mr. *Ricaut*, in a letter of his to the Royal Society, dated from *Constantinople*, Nov. 1667, says, “ That the water runs out of the *Euxine* sea into the *Propontis* with a wonderful swiftness, which is more wonderful in regard of the depth of the *Bosphorus*, being in the channel 50 or 55 fathom water, and along the land in most places the ships may lie on shore with their heads, and yet have 20 fathom water at their sterns.”

Besides these effects of raising and sinking the parts of the earth, there is a third sort, which is the transposing, converting, subverting, and jumbling the parts of the earth together; overthrowing mountains, and turning them upside down; throwing the parts of the earth from one place to another; burying the superficial parts, and raising the subterraneous. Of these kinds of changes, there are many instances in the former relations I have mentioned, and particularly that of *Linschoten* of the earthquake in the *Terceras*, and that of *Josephus Acosta*, of the earthquake upon the coast of *Chili*. And there are a multitude of others I could here set down, but I shall only mention some of them. “ Soon after (says *Acosta*, in the place before mentioned, which was in the year 1582) happened
“ that

“ that earthquake of *Arequipa*, which in a manner
 “ overthrew the whole city.” And a little before in
 the same place, he tells of a terrible earthquake in
Guatemala, in the year 1586, which overthrew al-
 most all the city, and that the *Vulcan* for above six
 months together continually vomited a flood of
 fire from the top of it. And a little after the same
 author, in the same place, says “ In the year
 “ 1581, in *Cugiano*, a city of *Peru*, otherwise call-
 “ ed the *Pear*, there happened a strange accident
 “ touching this subject; a village called *Angoango*,
 “ (where many *Indians* dwelt that were forcerers
 “ and idolaters) fell suddenly to ruin, so as a great
 “ part thereof was raised up and carried away, and
 “ many of the *Indians* smothered; and that which
 “ seemed incredible, yet testified by men of credit,
 “ the earth that was ruined and so beaten down,
 “ did run and slide upon the land for the space of
 “ a league and a half, as if it had been water or
 “ wax melted, so as it stopped and filled up a
 “ lake, and remained so spread all over the whole
 “ country.”

Nor are there wanting examples of this kind e-
 ven in this island. Mr. *Childrey*^c has collected se-
 veral out of *Cambden*; as that in *Herefordshire*,
 where “ In the year 1571, *Marcley Hill* in the east
 “ part of the shire, with a roaring noise, removed
 “ itself from the place where it stood, and for three
 “ days together travelled from its old seat. It
 “ began first to take its journey *Feb.* 17, being
 “ *Saturday*, at six of the clock at night, and by
 “ seven the next morning it had gone 40 paces,

^c Britann. Baconic.

“ carrying with it sheep in their cotes, hedge-
 “ rows, and trees, whereof some were overturn-
 “ ed; and some that stood upon the plain, are
 “ firmly growing upon the hill; those that were
 “ east were turned west, and those in the west
 “ were set in the east. In this remove it over-
 “ threw *Kinaston* chappel, and turned two high
 “ ways near a 100 yards from their old paths:
 “ the ground that they removed was about 26 a-
 “ cres, which opening itself with rocks and all,
 “ bore the earth before it for 400 yards space with-
 “ out any stay; leaving pasturages in the places
 “ of tillage, and the tillage overspread with pastu-
 “ rage. Lastly, overwhelming its lower parts,
 “ it mounted to a hill of 12 fathoms high, and
 “ there rested after three days travel.”

“ At *Hermitage* in *Dorsetshire*, says *Stow* in his
 “ *Summary*, Jan. the 3d 1582, a piece of ground
 “ of three acres removed from its old place, and
 “ was carried over another close, where alders and
 “ willows grew, the space of 40 rods or perches,
 “ and stopped up the highway that led to *Carne*,
 “ a market town; and yet the hedges that it
 “ was inclosed with inclose it still, and the trees
 “ stand bolt upright, and the place where this
 “ ground was, is left like a great pit.” And 'tis
 not a little observable that at the same time that
 these changes happened in *America*, the like also
 happened in *England*, of which I shall hereafter
 give divers other instances, and shall also deduce
 corollaries, that may otherwise seem very strange,
 and yet I question not to prove the truth of them.

Pliny

Pliny says ^f *Maximus terræ memoria mortalium extitit motus, &c.* “ There happened once (which I found
 “ in the books of the *Tuscan* learning) within the
 “ territories of *Modena*, *L. Marcius* and *S. Julius*
 “ being consuls, a great wonder of the earth : for
 “ two hills encountered each other, charging one
 “ another with a great crash, and retiring again,
 “ a great flame and smoke in the day-time issuing
 “ out from between them to the sky, while a great
 “ many of the *Roman* knights, their friends and
 “ travellers, beheld it from the *Æmylian* road.
 “ With this conflict, and meeting together, all the
 “ country houses were dashed to pieces, many a-
 “ nimals that were between them perished. This
 “ happened a year before the *Social* war. I know
 “ not whether it were more pernicious to *Italy* than
 “ the civil wars. No less a wonder was that in
 “ our age, in the last year of *Nero*, as we have
 “ shewn in our acts, when meadows and olive trees,
 “ the publick way lying between them, went into
 “ contrary (*exchanged*) places, in the *Marrucine*
 “ territory, on the lands of *Vestius Marcellus*, a
 “ *Roman* knight, procurator under *Nero*.”

There are many of the like instances to be met with in authors, of the placing parts perpendicular or inclining, which were before horizontal; of the turning of other parts upside downwards, of throwing parts from place to place; of stopping the passage of rivers, and turning them another way; of swallowing some rivers, and producing others anew; of changing countries from barren to fruitful, and from fruitful to barren; of making islands

^f Hist. nat. lib. ii. cap. 18.

join to the continent, and separating parts of the continent into islands. There are other relations which mention the vast spaces of ground, that have been all at once shaken and overturned; some of 500 miles in length, and a 150 in breadth: of the communication of *Vulcans*, which are, as it were, the nostrils, or constant breathing places of these monsters, tho' placed at a very great distance one from another, by subterraneous caverns. Other relations furnish us with instances of the substances they vomit out; such as pumice stones, and several other sorts of calcined and melted stones, and rocks, ashes, minerals, hot water, sulphur, flame, smoke, and various other substances.

In others we find instances of liquefactions, vitrifications, calcinations, sublimations, distillations, petrifications, transformations, suffocations, and infective, or deadly steams destroying all things near them, which probably may be one cause of the scarcity of relations, where 'tis probable, there have been so very many effects wrought in the world, of this kind. But these I shall not insist upon.

There is only one thing more, that I think pertinent to our present purpose, and that is the universality of this active principle: there is no country, almost in the world, but has been some time or other shaken by earthquakes, that has not suffered some, if not most part of these effects. *Seneca* says [§] *omnia ejusdem sortis sunt*, &c. “ All things
“ are subject to the same chance; though they are
“ not yet moved they are moveable; for we err,

[§] In præfat. lib. vi. quæst. nat.

“ if

“ if we believe any part of the earth excused and
 “ freed from this hazard ; all are subject to the
 “ same law ; nothing is made by nature so fixt as
 “ to be immoveable ; some sink at one time, some
 “ at another. And as in great cities, now this
 “ house, now that house hangs tottering on props ;
 “ so on the great face of the earth, now this part
 “ prevails, now that. *Tyre* formerly was remarka-
 “ ble for its destruction : *Asia* lost at once twelve
 “ cities. Whatever the power may be, the for-
 “ mer year *Achara* and *Macedonia* felt it, now
 “ *Campania*. Fate takes its rounds, and repeats
 “ what it had long before acted : it brings some
 “ things often on the stage, some seldom ; but suf-
 “ fers nothing to remain absolutely free and un-
 “ touch’d. Not we men only are brought forth
 “ short liv’d, frail beings : cities, countries, shores,
 “ nay the sea itself, are the slaves of fate. Why
 “ therefore do we flatter ourselves that the gifts of
 “ fortune will stick by us, or that happiness will
 “ observe any rule or measure ; happiness, the
 “ most fleeting of all human things ! They that pro-
 “ mise to themselves all things fixt, surely never
 “ think that the ground we stand upon is itself un-
 “ fixt. Nor was that the frailty only of *Campa-*
 “ *nia* or *Achaia* ; ’tis the same in all soils and coun-
 “ tries, to be loosely joined and compacted, but
 “ easily, and by many ways dissolved ; the whole
 “ remains, while each part changes and sinks into
 “ ruin and alteration.”

Thus we see all countries in the world are sub-
 ject to these convulsions, but those most of all,
 that are most mountainous : such are usually, all
 the

the sea coasts. Therefore *Pliny* says, that “ The
 “ *Alpes* and *Apennine* mountains have very often
 “ been troubled with earthquakes; maritime places
 “ are most shaken, nor do the mountainous escape,
 “ for I have found that the *Alpes* and *Apennines*
 “ tremble.”

For most probably those that are most mountainous, are most cavernous underneath; to countenance which opinion, I have taken notice in certain very high cliffs towards the sea, where the hills seemed as it were cleft afunder, the one half having been probably foundered and tumbled into the sea, and the other, as it were remaining, that at the bottom, near the water, for almost the whole length, there were very many large caverns, which by several circumstances, seemed to be made before the access of the sea thereunto, and not by the washing and beating of the waves against the bottom of the cliffs: for I observed in many of them, that the plates or layers, as I may so call those parts between the clefts in rocks, and cliffs to lean contrary ways, and not to meet, as it were, at the top like the roof of a house; and others of them in other forms, as if they had been caverns left between many vast rocks tumbled confusedly one upon another. And indeed I cannot imagine, but that under these mountains, islands, cliffs or lands, that have been much raised above their former level, there must be left vast caverns, whence all that matter was thrown, where probably may be the seat or place of the generation of those prodigious powers. But this only by the by, for I intend not here to examine the causes of their beginnings, force, and
 powerful

powerful effects, nor of their remaining, ceasing, renewing, or the like : it being sufficient for my present purpose, to shew that they have been certainly observed to produce those extraordinary effects, from what cause soever they proceed : that they have been heretofore in many places where they have now ceased for many ages ; and that they have lately happened in places where we have no history that does assure us they have been heretofore : that they have turned plains into mountains, and mountains into plains ; seas into land, and land into seas : made rivers where there were none before, and swallowed up others that formerly were : made and destroyed lakes ; made peninsulas islands, and islands peninsulas : vomited up islands in some places, and swallowed them down in others ; overturned, tumbled and thrown from place to place cities, woods, hills, &c. covered, burnt, wasted, and changed the superficial parts in others ; and many the like strange effects, which since the creation of the world, have wrought many very great changes on the superficial parts of the earth, and have been the great instruments or causes of placing shells, bones, plants, fishes, and the like, in those places, where, with much astonishment, we find them.

Concerning the vicissitudes that places are subject to in relation to earthquakes, I find a memorable passage sent by *Paul Ricaut*, Esq; now consul at *Smyrna*, dated *Nov. 23, 1667*. “ *Constantinople* “ is not now subject to earthquakes as reported in “ former times, there having not happened in the “ last seven years, in which I have been an inha-
 K “ bitant

“ bitant there, above one of which I have been
 “ sensible; but within the twenty days, in *Smyr-*
 “ *na*, fell out an earthquake which dangerously
 “ shook all the buildings, but did little or no
 “ harm: the ships in the road, and others at an
 “ anchor, about three leagues from hence, were
 “ sensible of it. It is reported that this city hath
 “ been already seven times devoured by earth-
 “ quakes, and it is prophesied, that it shall be so
 “ again as soon as the houses reach the old castle
 “ upon the top of the hill, on the side of which
 “ remains the ruins of the old city, and the tomb
 “ of *St. Polycarp*, *St. John*’s disciple, still pre-
 “ served by the *Greeks* in great veneration.”

There is another cause which has been also a great instrument in promoting the alterations on the earth’s surface, the motion of water; whether by its descent from on high, as in rivers, thro’ the immediate fall of rain or snow, or by the melting of snow; or secondly, by the seas natural motions, as tides and currents; or thirdly, by its accidental motions from winds and storms. Of each of these natural historians abound in instances. The former principle seems to be that which generates hills, holes, cliffs and caverns, and all irregularity and asperity on the earth’s surface; and this is what endeavours to reduce them to their pristine evenness by washing down the tops of hills, and filling up the bottoms of pits, consonant to all the other methods of nature in working with contrary principles; by which there is a kind of continual circulation. Water is raised in vapours by one quality, and precipitated in drops by another; the
 I rivers

rivers run into the sea, and the sea supplies them. In the planets there is a projectile force which makes them endeavour to recede from the sun, and an attractive power, which keeps them from receding. The air impregnates the ground in one place, and is impregnated by it in another; all things almost circulate and have their vicissitudes: we have multitudes of instances of the wasting of the tops of hills, and of the filling and encreasing of the plains or lower grounds; of rivers continually carrying along with them great quantities of sand, mud, &c. from higher to lower places; of the seas washing cliffs away, and wasting the shores; of land-floods carrying away with them all things that stand in their way, and covering the lands with mud, levelling ridges and filling ditches. Tides and currents in the sea act in all probability what floods and rivers do at land; and storms effect that on the sea-coast, that great land-floods do on the banks of rivers. *Egypt*, as lying very low, and yearly overflowed, is enlarged by the sediment of the *Nile*; especially towards those parts where that river falls into the *Mediterranean*. The gulph of *Venice* is almost choak'd with the sand of the *Po*. The mouth of the *Thames* is grown very shallow by the continual supply of sand brought down with the stream. Most part of the cliffs which wall in this island, do yearly founder and tumble into the sea. By these means many parts are covered and raised by mud and sand, that lie almost level with the water, and others are discovered and laid open that for many ages have been hid.

Of this kind the Royal Society received a memorable account from the learned Dr. *Brown*, concerning a petrified bone of a prodigious bigness, discovered by the falling of some cliffs; the words of the relation are these, “ This bone (*which is now in their repository*) “ was found last year 1666, “ on the sea shore, not far from *Winterton* in *Nor-* “ *folk*, near the cliff after two great floods, some “ thousand loads of earth being torn away by the “ rage of the sea, as it often happens upon this “ coast, where the cliffs consist not of rock, but “ of earth. That it came not out of the sea may “ be conjectured, because it was found near the “ cliff; and by the colour of it, for if out of the “ sea it would have been whiter. Upon the same “ coast, but, as I take it, nearer *Hajborough*, di- “ vers great bones are said to have been found, “ and I have seen a lower jaw containing teeth, “ of a prodigious bigness, and something petri- “ fied. All that have been found on this coast, “ were after the falling of some cliff: where the “ outward crust is fallen off it clearly resembles “ the bones of whales, and great cetaceous ani- “ mals, upon comparing it with the skull and “ bones of a whale, which was cast upon the coast “ near *Wells*, and which I have by me, the weight “ whereof is 55 pounds.” To this may be added the *Chartham* news, or the discovery of the sea-horse, or *Hippopotamus*’s teeth printed in the *Philos. Trans.* N^o 272, p. 882.

Nor are these changes now only, but they have, in all probability, been of as long standing as the world. So ’tis probable there may have been se-
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veral

veral vicissitudes of changes wrought on the same part of the earth : it may have been of an exact spherical form, with the rest of the earths or planets, at the creation of the world, before the eternal command of the Almighty, that the waters under the heaven should go to their place, which before covered the earth, so as that it was ἀόρατος καὶ ἀκατασκεύαστος καὶ ὁκτος ἐπάνω τῷ ἀβύσσῳ καὶ πνεῦμα θεῶν ἐπεφέρετο ἐπάνω τῷ ὕδατι, invisible and incompleated, and the darkness of the deep was over it, (being all covered with a very thick shell of water which invironed it on every side, it being then, in all probability, created of an exact spherical figure; and so the waters, being of themselves lighter than the earth, must equally spread themselves over the whole surface of the earth) and where the breath of the Lord moved above or upon the surface of those waters. It may, I say, in probability, have been then a part of the exact spherical surface of the earth, and upon the command that the waters under the air or atmosphere (which seems to be denoted by στερέωμα or firmament; for the *Hebrew* word signifies an *expansum*) should be gathered together in one place, and that the dry land should appear. It may have been by that extraordinary earthquake (whereby the hills and land were raised in one place, and that the pits or deeper places, whither the water was to recede, and be gathered together, to constitute the sea were sunk in another) raised perhaps to lie on the top of a hill, or in a plain, or sunk into the bottom of the sea, and by the washing of waters in motion, either carried to a lower place to cover

some part of the vale, or else be covered with adventitious earth, brought down upon it from some higher place; which kinds of alterations were certainly very great by the flood of *Noah*, and several other floods we find recorded in heathen writers. If at least there were not somewhat of an earthquake which might again sink those parts, which had been formerly raised to make the dry land appear, and raise the bottom of the sea, which had been sunk for the gathering together of the waters. (which opinion *Seneca* ascribes to *Fabianus*) “ *Ergo* (says he) *cum affuerit illa necessitas temporis, multa simul fata causas movent nec sine concussione mundi tanta mutatio est, ut quidam putant, inter quos Fabianus est.* His description of the manner and effects of a flood, is fine, and very suiting to my present hypothesis. This part being thus covered with other earth, perhaps in the bottom of the sea, may, by some subsequent earthquakes, have since been thrown up to the top of an hill, where those parts, with which it was by the former means covered, may, in tract of time, by the fall and washing of waters, be again uncovered and laid open to the air, and all those substances which had been buried for so many ages before, and which the devouring teeth of time had not consumed, may be there exposed to the light of the day.

There are yet two other causes of the mutation of the superficial parts of the earth, which have wrought great changes in the world; and those are, either the seas overflowing a country or place, forced by some violent storms or hurricanes of wind, or through the overflowings of rivers by
great

great falls of rain, or something stopping their course. Of these we have many instances in voyages: and we have often here at *London* felt the effects of the wind driving in the tide with so great force as to have overflowed the banks and filled the streets and cellars. “ At *Chatmos* in *Lancashire*, says *Childrey*^h, is a low mossy ground, “ very large, a great part of which, according to “ *Cambden*, not long ago, upon the brooks swelling high, was carried quite away with them, “ whereby the rivers were corrupted, and a number of fresh fish perished. In which place now “ lies a low vale watered with a little brook, “ where trees have been digged up lying along, “ which are supposed by some to have come thus. “ The channel of the brooks being not scowered, “ the brooks have risen, and made all the land “ moorish that lay lower than others, whereby the “ roots of trees being loosened, by reason of the “ bogginess of the ground, or by the water finding a passage under ground, the trees have, either by their own weight, or by some storm, “ been blown down, and so sunk into that soft “ earth and been swallowed up: for ’tis observable “ that trees are no where digged out of the earth “ but where the soil is boggy; and even upon hills “ such moorish and moist grounds are commonly “ found; the wood of such trees burning very “ bright, like touch-wood (which perhaps is by “ reason of the bituminous earth in which they “ have been so long) so as some take them for fir-trees. Such mighty trees are often found in

^h Britann. Baconic. p. 167, 168.

“ *Holland*, which are thought to be undermined
 “ by the waves working into the shore, or by
 “ winds driven forwards and brought to those
 “ lower places where they settled and sunk.”

Againⁱ, “ The sea has eaten a great part of
 “ the land away of the eastern shires. There are
 “ on the shore of this shire (*Cumberland*) trees dis-
 “ covered by the winds sometimes at low water,
 “ which are else covered over with sand; and it is
 “ reported by the people dwelling thereabouts, that
 “ they dig up trees without boughs, out of the
 “ ground, in several places of the shire, and many
 “ trees are found and digged out of the earth of
 “ the isle of *Man*.”

Again^k, “ In divers parts of the low grounds
 “ and champain fields of *Anglesea*, the inhabitants
 “ every day find and dig out of the earth, the bo-
 “ dies of huge trees with their roots, and fir-trees
 “ of a wonderful bigness and length.”

Again^l, “ At the same time that *Henry II.* made
 “ his abode in *Ireland*, were extraordinary violent
 “ and lasting storms of wind and weather, so that
 “ the sandy shore on the coasts of *Pembrokeshire*,
 “ was laid bare to the very hard ground, which
 “ had lain hid for many ages, and by further
 “ search the people found great trunks of trees,
 “ which when they had digged up, they were ap-
 “ parently lopped, so that one might see the strokes
 “ of the ax upon them, as if they had been given
 “ but the day before: the earth looked very black,
 “ and the wood of these trunks was altogether like
 “ ebony. At the first discovery made by these

ⁱ Britan. Baconic. p. 171. ^k Ib. p. 150. ^l Ib. p. 142, 143,

“ storms,

“ storms, the trees we speak of lay so thick, that
 “ the whole shore seemed nothing but a lopped
 “ grove; whence may be gathered, that the sea
 “ hath overflowed much land on this coast, as it
 “ has indeed many countries bordering upon the
 “ sea, which is to be imputed to the ignorance of
 “ the *Britons*, and other barbarous nations, who
 “ understood not those ways to repress the fury of
 “ the sea, which we now do.”

And again^m, “ In the low places on the south
 “ side of *Cheshire*, by the river *Wever*, trees are
 “ often found by digging under ground, which
 “ people think have lain buried there ever since
 “ *Noah's* flood. *St. Bennet's* in the *Holm* hath
 “ such fenny and rotten ground (says *Cambden*)
 “ that if a man cut up the roots or strings of trees,
 “ it flotes on the water. Hereabout also are coc-
 “ kles and periwinkles sometimes digged up out
 “ of the earth, which makes some think, that it
 “ was formerly overflowed by the sea.”

The *lignum fossile* which is found in *Italy*, of which we have a good account given by *Francisco Stelluti*, from many circumstances of the history, seems to me to have been first buried by some earthquakes, and afterwards to be variously metamorphosed by the symptoms which usually follow them, and which this place is much vexed with, as is indeed almost all the country of *Italy*, for it emits hot steams and smoke proceeding from subterraneous fires, which do there often shift their places; burn the parts of some of those trunks into black and brittle coals; melt a kind of ore into the pores of

^m Ib. p. 129.

others;

others ; petrify the substance of another sort ; bake the dirt and clayish substances which have soaked into the pores of a fourth sort into a kind of brick ; rot the parts of others, and convert them into a kind of dirt or muddy earth ; and so act variously, and produce differing effects, upon those buried substances, according to the nature of the earths, minerals, waters, salts, heats, smoaks, steams, and other active instruments casually apply'd to the parts of the buried trunks, by the confusion of the earthquakes, and by immediate application, and long continuance, and digestion, as I may call it, in this laboratory of nature, transformed into other substances, and exhibit all those admirable phænomena mentioned by that author, whereby the buried bodies are transformed. Nor is it so much to be wondered at, that such substances as vegetables, should after many ages remain entire, and rather more substantially found than if they were newly cut down ; since if we consider the nature of decay and corruption in all kinds of animal and vegetable substances, we shall find that the chief cause of them is from the action of the fluid parts upon the solid, for the dissolving of them : and wheresoever the internal fluid is either first changed, or altered by the admixture of some heterogeneous substance, so as to lose that dissolving property, as by the addition of salt, spirit of wine, &c. or by incorporating with it, and hardening it into a solid substance, as in petrifications, &c. or secondly, exhaled by a gradual and gentle heat, and so the solid parts only left alone, and kept either dry, or filled with a fluid of an heterogeneous nature,

nature, such as unctuous and spicy juices with watery substances. Or, thirdly, congealed and hardened, either by cold, or the peculiar nature of the juice itself; such is freezing, and the hardening of the coralline plants, or submarine vegetables, horns, gums, bones, hair, feathers, &c. Wherefore, I say, bodies are by these means put into such a constitution, that the parts act not, and continue in that state, by being preserved from adventitious moisture, or softening by homogeneous fluids, they are, as it were, perpetual, unless, by extraordinary heat, many of those otherwise solid and unactive substances are made fluid by such active dissolvents; or unless they be immersed in such liquors or menstruums as do of themselves dissolve and work on them; we shall not, I say, wonder at the lastingness of these buried substances, if we consider also the various juices with which several parts of the earth are furnished; unctuous, watery, styptic, saline, petrificative, corrosive, and what not. There are some juices of the earth which do, as it were, perpetuate them, by turning them into stone. Others do so deeply pierce and intimately mix with their parts, that they wholly, as it were, change the nature of their substances, and destroy that property of congruity which all bodies generated in the air and water seem to have, which are very apt to be dissolved and corrupted by innate aerial and aqueous substances. Such are all kinds almost of oleaginous and sulphureous bodies, and divers saline and mineral juices. Others indeed do not preserve the very substance of those vegetables, but by insinuating

ating into their pores, and there, as it were, fixing, they retain and perpetuate the shape and figure, but corrupt and dissolve the interposed part of the vegetable; of all which kinds I have seen some specimens, as I have also of divers other substances, pickled, dried, candied, conserved, preserved, or mummified by nature. Where therefore the substances have happened to be buried with preservative juices, they have withstood the injury of time; but where those juices have been wanting, there we find no footsteps of these monuments of antiquity.

But to return to what I was prosecuting; another cause which may make alterations on the surface of the earth, is any violent motions of the air, whereby the parts of the earth, in dry weather, are transported from place to place, in the form of dust. Of this kind travellers tell us very strange stories as to the removal of the sands in the deserts of *Arabia*, and other deserts of *Africa*; and we have some instances of it here in *England*, to wit in *Norfolk* and *Devonshire*, in the former of which there are often found natural mummies which have been buried alive by those removing sands, and by their dryness preserved. But these greater and more sudden removals of sand and dust are not so universal, and therefore not so much to my present purpose; though possibly they may have been more frequent heretofore, which the layers of sands to be found in digging pits and wells seem to hint: but that which is most universal, is very slow, and almost imperceptible, namely the removing of the dust from the higher parts, and settling thereof in the lower, by the wind or motion of the air.

I might mention also another cause of the transposition of the superficial parts of the earth, and that is from the gradual subsiding or sinking into the earth of the more heavy, and the ebullition, or respective rising of the more light parts upwards. Hence we may observe, that many old and vast buildings and towers have sunk into the earth : and the like we may judge of those vast stones on *Salisbury* plain, as we find constantly in almost all stone monuments placed in church-yards, and in all old churches, unless placed on a very high place, and founded on some rock. This cause may possibly have great influence where the earth is very soft, spongy, or boggy ; and perhaps many of those trees which are found in boggy grounds, may have been buried, by having been either felled, or blown down with wind, or washed down by some inundation, well impregnated with mineral juices, and so made heavier than the subjacent earth, and swallowed into it. Several of the former relations do indeed pretty well agree with this hypothesis ; and I am very apt to think that where the surface of the earth has not been much altered since the creation, if any such there be ; if it were searched into, it would be found that the lightest parts lie next the surface, and the heavier in the lower parts ; which makes me imagine that the natural place of minerals is very deep under the surface of the earth, and possibly to be found under every step of ground, were search made to a sufficient depth ; and that the reason why we find them sometimes near the surface, as in mountains, is not because they were there generated, but because they have
been

been by some former subterraneous eruption, by which those hills and mountains were made, thrown up towards the surface of the earth. And as gold is the heaviest, so is it the scarcest of all metals: Nor do I at all question but that there may be other bodies or metals as much heavier than gold, as gold is heavier than common earth. To make these conjectures the more probable, see what Sir *Philiberto Vernatti* writes from *Batavia* in the *East Indies*, in answer to some queries sent him by the Royal Society. “ I have often felt earthquakes
 “ here, but they do not continue long. In the year
 “ 1656, or 57, (I do not remember well the time)
 “ *Batavia* was covered in one afternoon about two
 “ of the clock, with a black dust, which being
 “ gathered together, was so ponderous that it exceeded the weight of gold. It is here thought
 “ that it came out of a hill that burneth in *Sumatra*, near *Endrapeor*.”

These fiery eruptions in all probability come from a very great depth, and with a great violence; and possibly even that golden powder that is sometimes thrown up, may have somewhat conduced to the cause of the violence of it. We know not what method nature may have to prepare an *aurum fulminans* of her own, great quantities of which, being any ways heated, and so fired, may have produced the powder. However, whether so or not, it is very well worth trial to examine, whether the flower which may be catch'd in a glass body, upon fulminating a quantity of such powder gradually, by small parcels, would, by being ordered as common gold, make again an *aurum fulminans*: or whe-

whether this fulmination, which is a kind of inflaming of the body of gold, does not make some very considerable alteration in the nature and texture of it.

But to proceed to the last argument to confirm the sixth proposition I at first undertook to prove; namely, that very many parts of the surface of the earth have been transformed, transposed, and many ways alter'd since the first creation of it. And that which to me seems the strongest and most cogent argument of all, is this; that at the tops of some of the highest hills, and in the bottom of some of the deepest mines, in the midst of mountains and quarries of stone, &c. divers bodies have been, and daily are found, which if we thoroughly examine, we shall find to be the real shells of fishes, which, for these following reasons, we conclude to have been at first generated by the plastic faculty of the soul or life-principle of some animal, and not from the imaginary influence of the stars, or from any plastic faculty inherent in the earth itself so formed; the stress of which argument lies in these particulars.

I. That the bodies there found have exactly the form and matter, that is, are of the same kind of substance, for all its sensible properties, and have the same external and internal figure or shape with the shells of animals.

II. That it is contrary to all other acts of nature, that does nothing in vain, but always aims at an end, to make two bodies exactly of the same substance and figure, and one of them to be wholly useless,

useless, or at least, without any design that we can with any plausibility imagine.

III. Therefore, wherever nature works by peculiar forms and substances, we find that she always joins the body so framed with some other peculiar substance. Thus the shells of animals, whilst they are forming are joined with the flesh of the animal to which they belong. Peculiar flowers, leaves and fruit are appropriated to peculiar roots, whereas these on the contrary are found mixed with all kind of substances, in stones of all kinds, in all kinds of earth, sometimes exposed in the open air, without any coherence to any thing. This is, at least, an argument, that they were not generated in that posture they are found; that very probably they have been heretofore distinct and disunited from the bodies with which they are now mixt, and that they were not formed out of these very stones or earth, as some imagine, but derived their beings from some preceding principle.

IV. Wherever else nature works by peculiar forms, we find her always to compleat that form, and not break off abruptly. But these shells that are found in the middle of stones, are most of them broken, very few compleat, nay, I have seen many bruised and flawed, and the parts at a pretty distance one from another, which is an argument that they were not generated in the place where they were found, and in that posture, but that they have been sometimes distinct and distant from those substances, and then only placed, broken and disfigured by chance, but had a preceding and more noble principle to which they owed their form,
and

and by some hand of providence were cast into such places where they were filled with such substances, as in tract of time have condensed and hardened into stone. This, I think, any impartial examiner of these bodies will easily grant to be very probable, especially if he takes notice of the circumstances I have already mentioned. Now, if it be granted, that there have been preceding moulds, and that curiously figured stones do not owe their form to a plastic or forming principle inherent in their substances; why might not these be supposed shells, as well as other bodies of the same shape and substance, generated, none knows how, nor can imagine for what?

V. Further, if these be the apish tricks of nature, why does she not imitate several other of her own works? Why do we not dig out of mines everlasting vegetables, as grass, for instance, or roses, of the same substance, colour, smell &c. were it not that the shells of fishes are made of a kind of stony substance, which is not apt to corrupt and decay? Whereas plants and other animal substances, even bones, horns, teeth and claws, are more liable to the universal menstruum of time. 'Tis probable therefore, that the fixedness of their substance has preserved them in their pristine form; and not that a new plastic principle has newly generated them. Besides, why should we not then doubt of all the shells taken up by the sea shore, or out of the sea, (if they had none when we found them) whether they ever had any fish in them or not? Why should we not also here conceit a plastic faculty, distinct from that of the life principle

of some animal? Is it because this is more like a shell than the other? That, I am sure cannot be. Is it because it is more obvious how a shell should be placed there than the other? If so, 'twould be as good reason to doubt, if an anchor should be found at the top of a hill, as the poet affirms, or an urn or coins buried under ground, or in the bottom of a mine, whether it were ever an anchor or an urn, or a coined face, or made by the plastic faculty of the earth; than which, what could be more absurd? And those persons that will needs be so over confident of their omniscience of all that has been done in the world, or that could be, may, if they will vouchsafe, suffer themselves to be asked a question, who informed them? Who told them where *England* was before the flood; nay even where it was before the *Roman* conquest, for about 4 or 5000 years, and perhaps much longer; much more where did they ever read or hear of what *changes* and transpositions there have been of the parts of it before that? What history informs us of the burying of those trees in *Cheshire* and *Anglesea*? Who can tell when *Teneriffe* was made? And yet we find that most judicious men that have been there, and well considered the form and posture of it, conclude it to have been at first that way produced. But I suppose the most confident will quickly, upon examination, find that there is a defect of natural history. If therefore we are left to conjecture, then that must certainly be the best that is backed with most reason; that clay, and sand and common shells, can be changed and incorporated together into stones very hard. I have

I

already

already given many instances, and can produce hundreds of others, but that I think it needless, that several parts of the bottom of the sea have been thrown up into islands and mountains. I have also given divers instances, and those, some of them, within the memory of man, where 'tis not in the least to be doubted but that there may be found some ages hence several shells at the tops of those hills there generated; and as little, that if quarries of stone should be hereafter digged in those places, there would be found shells incorporated with them; and were they not beholding to this inquisitive and learned age for the history of that eruption, they might as much wonder how those shells should come there, and ascribe them to a plastic faculty, or some imaginary influence, as plausibly as some now do.

Now if all these bodies have been really such shells of fishes as they most resemble, and that they are found at the tops of the most considerable mountains in the world, as *Caucasus*, the *Alpes*, the *Andes*, the *Apennine* and *Pyrenean* mountains, and that 'tis not very probable they were carried thither by mens hands, or by the deluge of *Noah*, or by any other more likely way than that of earthquakes; 'tis a very cogent argument that the superficial parts of the earth have been very much changed since the beginning, that the tops of the mountains have been under water, and consequently also that divers parts of the sea's bottom have been heretofore mountains.

The seventh proposition was, that 'tis very probable divers of these transpositions and metamorphoses

phoses have been wrought here in *England*. Many of its hills have probably been heretofore under sea. Of the latter of these I have given many instances already, and the first is probable from the great quantity of shells found in the most inland parts of the island; in hills, plains, bottoms of mines and middle of mountains and quarries. Of this kind are the infinite numbers in the *Portland*, *Purbeck*, *Burford* and *Northamptonshire* stones: out of which I have often pickt muscles, cockles, periwinkles, oysters, scallops, &c.

'Tis improbable that either mens hands, or the general deluge, which lasted but a little while, should bring them there: nothing more likely and sufficient than an earthquake, which might heretofore raise these islands of *Great Britain* and *Ireland* out of the sea, as it lately did those in the *Canaries* and *Azores*, in the sight of divers who are yet alive. Possibly *England* and *Ireland* might be raised by the same earthquake by which the *Atlantis*, if we will believe *Plato*, was sunk.

Eighthly, that most of these mountains and inland places where these kind of petrified bodies and shells are found at present, or have been heretofore, were formerly under water; and that from the descending of the waters to some other place, by the translation of the centre of gravity of the whole mass, or rather by the eruption of some subterraneous fires, or earthquakes, great quantities of earth have been deserted by the water, and laid bare and dry. That divers places have been so raised, has been already proved from many histories; why then may not all of them have the same original?

original? There is no coin can so well inform an antiquary that such and such a place was once subject to such a prince, as fossil shells will certify a natural antiquary, that such and such places have been under water: and methinks providence seems to have designed these permanent shapes, as monuments and records to instruct succeeding ages of what pass'd in preceding ones.

Ninthly, it seems probable, that the tops of the most considerable mountains in the world have been under water, and were raised to that height by some eruption; so that those prodigious piles are nothing but the effects of some great earthquakes. This truth, 'tis likely, the poets have veiled under the feign'd story of the giants, those earth-born brothers, waging war with the gods, and heaping up mountains upon mountains; *Offa* and *Olympus* upon *Peleon*, and to hurl up great stones and fire against heaven, but that at last overcome by *Jupiter's* thunder, they were buried under mountains, and the chiefest of them, *Typhæus* and *Enceladus* under *Sicily*, according to *Ovid*ⁿ and *Virgil*^o.

And as the poets had particular stories and giants for *Sicily* and *Ætna*, so had they also for other vulcano's and from the frequency of them in former ages about *Greece* and other parts of the *Mediterranean*: *Sophocles* calls them ὁ γηγενὴς στρατὸς γιγάντων, the earth-born army of the giants. And that nothing but earthquakes were meant by these giants, may be further collected from the place where they were said to be bred, the *Phlegrean*

ⁿ *Metamorph. lib. v.*

^o *Æneid. lib. iii.*

fields in *Campania*, part of which, now called *Vulcan's* court, is the vent of many subterraneous fires. Besides, how well do their actions agree with the effects of earthquakes? For they are said to throw up burning trees against heaven, and huge rocks, and vast hills, which, falling into the sea, became islands, and mountains, lighting on the land. In a word, he that will read the description of the most notable of them, *Typhæus*, and compare it with a natural description of an earthquake, will easily explicate the several parts of the poets mystical descriptions.

Though it be hard to prove this theory *positively*, thro' deficiency of natural history, yet if we consider that the *Alps*, *Apennine* and *Pyrenean* hills, much the highest in *Europe*, have been infested with earthquakes, both formerly and lately, as we have several histories that testify; and if other eruptions and earthquakes have raised mountains even out of the bottom of the sea, and that the power of included fire is sufficient to move and raise even a whole country all at once, for some hundreds of miles, as historians assure us; if we consider all this I say, we may have reason to find it more than probable. And if to this we add the universal silence in history, of any part of *Europe*, nay of the whole world for almost 200 years after the flood, I think there will be much less scruple to grant that the many high mountains on whose tops are found such numbers and varieties of true sea shells, may have been heretofore raised up from under the sea, and now are sustained by the sinking of other

other parts into the places from whence they were raised.

The tenth and last proposition is, that it seems not improbable but that the greatest part of the inequality of the earth's surface may have proceeded from the subversions and overturnings of some preceding earthquakes.

To prove this probability, I might repeat the argument, already urged; I could also instance in a multitude of other smaller effects of earthquakes, making the surface of the earth irregular, but they are so numerous and well known that I shall not insist on them. I might add also the universality of earthquakes, there being no part of the known world but we find to have been shaken by them. Thus much only I shall offer at present, that from what I have instanced about petrifications, and hardening of several substances, it seems very likely that the earth in the beginning consisted for the most part of fluid substances, which by degrees have settled, congealed, and been converted into stones, minerals, metals, clays, earth, &c. and so in process of time lost their fluidity, and that the earth itself waxes old almost in the same manner as animals and vegetables do; its moisture gradually decaying or wasting, either into air, and from thence into æther; or else by degrees the parts communicating their motion to the fluid æther, grow immoveable and hard. Therefore if it be probable that the parts of the earth have been formerly softer and more yielding, how much more powerful might earthquakes then be in breaking, raising, overturning, and otherwise changing the superfi-

cial parts of the earth: besides they might be more frequent before the fuels of the subterraneous fires were much spent; for that those do also waste and decay, is evident from the extinction and ceasing of several vulcano's that have heretofore raged; which considerations may afford us sufficient arguments to believe that earthquakes have heretofore, not only been much more frequent and universal, but likewise much more powerful.

Corollaries deduced from the preceding Propositions.

I. **T**HAT there may have been in past ages, whole countries, either swallowed up into the earth, or sunk so low as to be drowned by the coming in of the sea, or divers other ways quite destroyed; as *Plato's Atlantis*, &c.

II. That there may have been as many countries new made and produced, by being raised from under the water, or from the hidden parts of the body of the earth, as *England*.

III. That there may have been divers species of things wholly destroyed and annihilated, and divers others changed and varied: for since we find that there are some kinds of animals and vegetables peculiar to certain places, and not to be found elsewhere; if such places have been swallowed up, 'tis not improbable but that those animal beings may have been destroyed with them; and this may be true both of aerial and aquatic animals: for those animated bodies, whether vegetables or animals,

mals, which were naturally nourished or refreshed by the air, would be destroyed by the water. And this I imagine to be the reason why we oft find the shells of divers fishes petrified in stone, of which we have now none of the same kind; as divers of those snail or snail stones whereof great varieties are found about *England*, and dug out of the midst of the very quarry, sometimes, in *Portland*, of a prodigious bigness.

IV. That there may have been divers new varieties generated of the same species, and that by the change of the soil by which it was produced: for since we find that the alteration of the clime, soil and nourishment often produces a very great alteration in vegetables; 'tis not to be doubted but that alterations also of this nature may cause a very great change in the shape, and other accidents of an animated body. And this I imagine to be the reason we find divers kinds of petrified shells, of which kind we have none now naturally produced.

V. 'Tis not impossible but that there may have been a preceding learned age, wherein possibly as many things may have been known as are now, and perhaps many more, all cultivated and reduced to their highest pitch; and all these annihilated, destroyed, and lost by succeeding devastations.

VI. 'Tis not impossible but that this may have been the cause of a total deluge, which may have brought on a destruction of all things then living in the air: for if earthquakes can raise the surface of the earth in one place, and sink it in another, so as to make it uneven and rugged with hills and pits, it may, on the contrary, level those moun-
tains

tains again, and fill those pits and reduce the body of the earth to its primitive roundness, and then the waters must necessarily cover all the face of the earth again, as it did at the beginning of the world, and by this means not only a learned age may be wholly annihilated, and no relicks of it left, but also a great number of the species of animals and plants.

VII. 'Tis not impossible but that some of these great alterations may have altered also the polar directions of the earth; so that what is now under the pole, or æquator, or any other degree of latitude, may have formerly been under another: for since 'tis probable that divers of these parts that have such a quality, may have been transposed, 'tis not unlikely but that the æquatoreal axis of the whole may be alter'd by it, after the same manner, as we may find by experiments on a loadstone, that the breaking off and transposing the parts of it, do cause a variation of the magnetic axis.

Of Earthquakes in the Leeward Islands.

THE greatest objection against my theory of the varieties observable in the present superficies of the earth, as caused by the power of earthquakes, or eruptions of fiery conflagrations inkindled in the subterraneous regions, is, I find, the want of history to confirm it. For that all places, countries, seas, rivers, islands, &c. have all continued the same for so long a time as we can reach backwards with any history. All Greece, and

and the *Grecian Islands*, *Italy*, *Ægypt*, &c. are all the same as they were 2000 years since, and therefore they were so from the creation, and will be so to the general conflagration; and as to the effects of earthquakes, first, they have happened but seldom; and, secondly, they have not produced any notable change, such as I have supposed them to be the authors and efficient of. So that it seems but a bare conjecture, and without ground and foundation sufficient to found and raise such a superstructure of conclusions, as I have thereupon raised.

In answer to which, I shall not repeat here what I have formerly produced; but shall take notice of some particular instances which have happened within our own memory, and more particularly of the late instance which hath happened in the *Antilles*, of which we have an account in the *Gazette*, namely in that of *June* 30th and another in that of *June* 16th preceding, both which relations, tho' they are but short and imperfect, as to what I could have wished for and shall endeavour to obtain; yet, as they are, they will be found to contain many particulars which very much illustrate and confirm my conjectures. And tho' the particular effects were not so great as to equalize those which I have supposed to have been the productions of former eruptions; such as the raising of the *Alpes*, *Pyreneans*, *Apennine*, *Andes*, and the like mountains; or the making of new lands, islands, &c. or the sinking of countries and drowning of islands, as the *Platonic Atlantis* and contiguous islands, yet if they be considered, they will be found to be of the

the same nature, and to differ only in magnitude, but not in essence.

The first account is dated from *Nevis, April* the 30th, (1690) in these words. “ On *Sunday* the
 “ 6th instant, about five o’clock in the evening,
 “ was, for some minutes, heard a strange hollow
 “ noise, which was thought to proceed from the
 “ great mountain in the middle of the island, to
 “ the admiration of all people; but immediately
 “ after, to their great amazement, began a mighty
 “ earthquake; with that violence, that almost all
 “ the houses in *Charles Town*, that were built of
 “ brick or stone, were, in an instant, levelled with
 “ the ground, and those built with timber shook,
 “ that every body made what haste they could to
 “ get out of them. In the streets the ground in
 “ several places clove about two foot asunder, and
 “ hot stinking water spouted out of the earth a
 “ great height. The sea left its usual bounds
 “ more than a third of a mile, so that very large
 “ fish lay bare upon the shore, but the water presently returned again: and afterwards the same
 “ strange motion happened several times, but the
 “ water retired not so far as at first. The earth
 “ in many places was thrown up in great quantities, and thousands of large trees went with it,
 “ which were buried and no more seen. ’Tis
 “ usual at almost every house to have a large cistern, to contain the rain water, of about nine
 “ or ten foot deep, and fifteen or twenty foot diameter; several of which, with the violence of
 “ the earthquake, threw out the water eight or
 “ ten foot high; and the motion of the earth all
 “ over

“ over the island was such, that nothing could be
 “ more terrible. In the island of *St. Christopher*
 “ (as some *French* gentlemen who are come hither
 “ to treat about the exchange of prisoners do re-
 “ port) there has likewise been an earthquake,
 “ the earth opening in many places nine foot, and
 “ burying solid timber, sugar mills, &c. and
 “ throwing down the *Jesuits* college, and all other
 “ stone buildings. It was also in a manner as
 “ violent at *Antego* and *Montserrat*; and they had
 “ some feeling of it at *Barbadoes*. Several small
 “ earthquakes have happened since, three or four
 “ in 24 hours; some of which made the biggest
 “ rocks have a great motion, but we are now in
 “ great hopes there will be no more.”

This is the whole of the relation from *Nevis*:
 but the other account from *Barbadoes*, of the 23d
 of *April*, takes notice of other particulars than what
 are mentioned in this letter: the printed account
 is as follows. “ About three weeks since there
 “ were felt most violent earthquakes in the *Leeward*
 “ *Islands* of *Montserrat*, *Nevis* and *Antego*; in the
 “ two first no considerable mischief was done,
 “ most of their buildings being of timber; but
 “ where there were stone buildings, they were ge-
 “ nerally thrown down, which fell very hard in
 “ *Antego*, most of their houses, sugar mills, and
 “ wind mills being of stone. This earthquake
 “ was felt in some places of this island, but did
 “ no manner of hurt to men or cattle; nor was a-
 “ ny lost in the *Leeward Islands*, it happening in the
 “ day-time. It is reported to have been yet more
 “ violent in *Martinico*, and other *French* islands,
 “ and

“ and several sloops which came from *Nevis* and
“ *Antego*, passing between *St. Lucia* and *Martinico*,
“ felt it at sea; the agitation of the water being
“ so violent, that they thought themselves on rocks
“ and shelves, the vessels shaking as if they would
“ break in pieces. And others passing by a rock
“ and uninhabited island, called *Rodunda*, found
“ the earthquake so violent there, that a great
“ part of that rocky island split and tumbled into
“ the sea, and was there sunk, making a noise as
“ of many cannon, and a very great cloud of dust
“ ascending into the air at the fall. Two very
“ great comets have lately appeared in these parts
“ of the world, and in an hour and a quarter’s
“ time the sea ebbed and flowed to an unusual de-
“ gree, three times.”

In these relations are many considerable effects produced which will much confirm my former doctrine about earthquakes. And first, it is very remarkable, that this earthquake was not confined to a small spot or place of the earth, such as the eruption of *Ætna* or *Vesuvius* out of one mouth, but it extended above five degrees, or 350 miles in length, from *Barbadoes* to *St. Christopher’s*, and possibly much farther: and tho’ there might not be opportunities of noticing the effects in all places of the sea where it might have been felt; yet by the few instances related, we may guess that its effects might be very considerable, and sensible a great way in breadth under the sea; for we find that the succussions were felt by vessels sailing over some parts of the sea so affected, and those so violent, as if the vessels had struck upon rocks; which
could

could be from nothing else but the sudden rising of the bottom of the sea, which raised the sea also with it, like water in a tub or dish: and that this was of that nature, does further appear by the unusual tides at *Barbadoes* mentioned in the last relation, which in all probability was nothing else but waves propagated from the places where the ground underneath, and the sea above, had been, by the concussions of the earthquake, raised upwards. This appears also farther by the recess of the sea at *Nevis*; for the whole island being raised by the swelling or eruption of the vapour or fire underneath, made the sea run off from the shores, 'till it settled down again, after the vapour had broken its way out thro' the clefts that were made by those swellings. From all which particulars, and several others, 'tis manifest, that the space of earth raised or struck upwards by the impetuosity of the subterraneous powers, was of great extent, and might far exceed the length of the *Alpes* or the *Pyreneans*, &c.

Another notable particular is the recess of the sea from the shore, and the leaving the fish upon the so raised bottom: and tho' this part soon after sunk again, so that the sea returned to its former bounds; yet if some other parts of the subterraneous ground had filled up the new made cavity, or had so tumbled as to support the so raised parts, then it would have left some such kind of tract as is now in *Virginia*, where, for many miles in length, the lowland is nothing but sea sand and shells, which have been, in all probability, so raised into the air, and there supported and kept from sinking down

down again into the sea. There can be no doubt that the shells taken up from this tract did belong to fish of their kind, they remaining perfect scallop shells to this day.

A third remarkable particular, is the burying and covering of thousands of trees by the earth which was thrown up by the eruption. This is a plain instance how trees found buried in many parts of *England* may have come to be so deposited, probably at a time before any writings or records were kept here; or, if since the *Roman* conquest, the neighbouring inhabitants might have perished in the catastrophe, whilst those at a distance might not think themselves sufficiently interested in transmitting the account to posterity. *Aristotle* speaking of the like events⁹, says, “ Now, because
 “ many of these changes happen but slowly, in
 “ comparison to the quickness and shortness of the
 “ life of man, therefore they are hardly taken notice
 “ of, a whole generation having passed away before such changes have come to perfection. Other catastrophies that have been more quick,
 “ have been forgotten, by reason that such as escaped them were removed to some other parts,
 “ and there the memory of them was soon lost; at least a longer tract of time did quite obliterate
 “ the remembrance of them, and the transplanting
 “ and transmigration of people from place to place
 “ much contributed thereto.” This is made plain by the little remembrance there was found in *America* of their preceding estate, when they were first visited by the *Spaniards* and other *Europeans*.

⁹ Meteor. lib. i. cap. 14.

A fourth particular remarkable in these relations, is the chopping and cleaving of the earth and rocks, and the spouting of stinking water out of them to a great height, as also of smoke or dust; which serves to explain the reason and causes of the flaws and veins in marbles and other stones: for by the power and violence of the subterraneous heavings or succussions, the stony quarries become broken, flawed and cleft, and subterraneous mineral waters impregnated with saline, metalline, sulphureous, or other substances are driven into them and fill them up, which having petrifying qualities, do, in process of time, petrify in those clefts, and thereby form a sort of stony veins, of different colour, hardness, and other qualifications, than what the parts of the broken quarry had before, and oft-times inclose divers other substances, by their petrifying quality, which have happened to fall into those clefts; and thence sometimes there are found shells petrified in the middle of a vein, and other substances. These clefts or chaps happen not only upon the land, but even under the sea; so that not only the sea water may descend and fill them up, but may carry with it sand, shells, mud, and divers other matters from the bottom of the sea, that then lay above it; there to be in process of time changed into stone, somewhat of the nature of that which has been so cleft.

Fifthly, 'tis worth noting, that this earthquake happened at so great a distance from the main land and great continent, and that the noise of the same was first observed to begin at the great mountain in the middle of the island of *Nevis*, not but that

in other parts it might have begun sooner or at other times; from which I infer: first, that it seems probable that this great mountain may have been first produced by some such power, and so have great cavities within its bowels formed by such a preceding eruption, the dislocated parts not returning each to his own place. And next, that it may hence seem probable, that some such preceding earthquake, perhaps more violent for the first time, might not only be the cause of raising this mountain, but of lifting up from the bottom the whole isle, nay possibly of all the islands of the *Antilles*, since one seems as possible as the other, and the northermost of them all seems to hint as much, if considered in the map: besides, there seems to be many instances of a like nature, as in the *Canaries*, *Teneriffe* is a remarkable character of such a supposition; to which may be added *Del Fuego* and *Madeira*; *Sicily*, *Strombulo* and *Lipary* in the *Mediterranean*; *Iceland* in the *North Sea*; *Mascarenos* near *Madagascar*; with the many islands of the *Archipelago*, which though they have now no great sign of burning mountains, yet to this day earthquakes are very frequent there, and ancient traditions do preserve somewhat of the memory of very great alterations that have happened from such causes. And I do not question but that all islands which lie far in the sea, would plainly manifest, if they were thoroughly examined, whence they have proceeded, and this by characters of nature's writing, which to me are far beyond any other record whatsoever.

Sixthly,

Sixthly, 'tis very remarkable that the Isle of *Rounda*, being all an uninhabited rock, was split, and part of it tumbled down and sunk into the sea, with a noise as of many cannon; sending up at the same time a great cloud of dust, as they term it, which in all probability was also mingled with smoak: which puts me in mind of the phænomena I observed lately, when the powder mill and magazine at *Hackney* blew up; for besides the very great noise of the blow I heard, being within a mile of it in the fields, I observed immediately a great white cloud of smoak to rise in a body to a great height in the air, and to be carried by the wind for two miles and better, without dispersing or falling down, and perfectly resembling the white summer clouds. From these phænomena of the earthquake it seems very probable, that it proceeded from such subterraneous inkindling as resembles gun-powder, both by the noise it yielded, and its suddenness of firing, and its powerful expansion when fired. Next, the splitting of the rocky island proves its power to be very great, which is proved yet farther by the blow and strokes it communicated to the sea, and to the ships that sailed on it; for no slow motion whatever could have communicated such a concussion through the water to the vessels upon it, but it must be as sudden as that of powder; for if it had been a gradual rising from the bottom, the sea would gradually have ran off from it, and upon its sinking again have gradually returned, and the vessels on it would only have been sensible, at most, but of a current or running of the water, to or from the place of sink-

ing or rising, somewhat like the effect which happened at *Nevis*; which plainly shews, that besides the sudden strokes or concussions, there was also a considerable rising and sinking of the whole island: but what I principally note under this head, is, a good part of the island's tumbling and sinking into the sea, which shews how many parts of the earth come to be buried, and displaced from their former situations, and thence how ships anchors, bones, teeth, &c. that have been digged up from great depths, may have been there buried.

Seventhly, 'tis remarkable also, that this eruption sent up into the air vast clouds of dust and smoke, which for the most part must soon fall down again into the sea, or contiguous parts of the island. This will give a probable account how the layers of the superficial parts of the earth may come to be made; for the most part of this dust must come down to the bottom first, and settle to a certain thickness, and make a bed of gravel, and then will follow beds of coarse sand, then beds of a finer sand, and last, of clays or moulds of several sorts. Again, much of that which fell upon the higher parts of the island, will, by the rivers, be washed down into the vales, and there produce the like beds or layers of several kinds, and so bury many of the parts that were before on the surface. Thus plants and vegetable substances may come to be buried, and the bones and teeth of the carcasses of dead animals: these may also sometimes be buried under beds or crusts of stone, when the parts that thus make the layers, chance to be mixed with such subterraneous substances as carry with them

them a petrifying quality. I could heartily wish that some care were taken, that a more particular account were procured of these earthquakes whilst their effects were fresh in memory, that they might be recorded and added to the collections of natural history: and for the same end it were desirable to know what former earthquakes have been taken notice of in these islands, as *Jamaica*, *Cuba*, *Hispaniola*, *Porto Rico*, &c. for the circumstances of such accidents, if they be not collected and recorded whilst the spectators are in being, are soon forgotten, and lost, or not regarded by succeeding generations, as *Aristotle* has well observed in a chapter I before quoted.

*Why Islands and Sea Coasts are most
subject to Earthquakes.*

WHAT is most remarkable in these earthquakes in the *Leeward Islands*, is, that they have all happened to places not far distant from the sea, or even under the sea itself, though the eruptions have been, for the most part, on the land. So that there seems to be some reason to conjecture, as Signior *Bottoni* does in his *Pyrologia Topographica*, that the saline quality of the sea water may conduce to the production of the subterraneous fermentation with the sulphureous minerals there placed, which an experiment lately exhibited before the Royal Society, makes still more probable; for it appeared that the mixing of spirit of salt with iron, did produce such a fermentation

as raised a vapour or steam which by an actual flame was immediately fired like gun-powder, and if inclosed would, in all probability, have had a like effect of raising and dispersing of those parts that bounded and imprisoned it. Now, the melted matter vomited out of *Ætna* in the year 1669, was very much like to melted or cast iron, and I doubt not but that there may be much of that mineral in it; besides the foot of that mountain extends even to the very sea, and in all probability may have caverns under the sea itself, which is argued also from the simultaneous conflagration of *Strombolo* and *Lipary*, islands considerably distant from it by sea, where it is generally believed that there may be cavernous passages between them, by which they communicate; so that sometimes it begins in *Ætna*, and is communicated to *Strombolo*, and reciprocally communicated to *Mongibel*.

This may possibly afford a probable reason why islands are now more subject to earthquakes, than continents and inland parts; and indeed how so many islands came to be dispersed up and down in the sea; for that these fermentations may have been wrought up in submarine parts of the earth, and being ripe may have taken fire, and so have had force enough to raise a sufficient quantity of the earth above it, to make its way through the sea, and there gain a vent, as that of the *Canaries* did in the year 1639, which, if sufficiently copious, may produce an island, as that did for a time, but has since again sunk under the surface of the sea. But the island of *Ascension*, which by all appearance
seems

seems to have been produced the same way, still remains a witness to prove this hypothesis. Like testimonies are the island and *Pike* of *Teneriffe*, *Heccla* of *Iceland*, *Bearenberg* of *John Mayens* or *Trinity Island*, *Del Fuego* of the *Cape Verd* islands, *Ternate* of the *Moluccas*, *Mascarenas*, some about *Madagascar*, and the *Antilles* or *Caribbees*. And tho' the fires be extinct in many of the other islands, yet 'tis observable that the prodigious high mountains or sugar-loaf pikes do yet remain as marks of what they had been heretofore; so the *Pike* of *Fayal* among the *Terceras*, and the whole island of *St. Helena* and several about *Madagascar* and in the *East Indies*, and the *Antilles*, and that of *St. Martha* mentioned by *Dampier*, seem plain evidences of the original causes of them all, tho' at various periods of time.

Of the Causes of EARTHQUAKES.

THE materials that serve to produce earthquakes, I conceive to be somewhat analogous to the materials of gun-powder; not that they must necessarily be the very same, either as to the parts, or as to the manner or order of composition, or as to the way of inkindling or accension; for that as much the same effect may be produced by differing agents, so the methods and order of proceeding may be altogether as various: a clear instance of which we have in the phænomena of lightning, wherein we may observe that the effects are very like to the effects of gun-powder. For we have first the flash of light, which is very sud-

den, very bright, and of very short continuance, being almost momentaneous. Next we may observe the violence of the crack, which is likewise momentaneous, if it be single, but if there be many particular accensions which contribute to this effect, and those made at several distances, then the thunder is heard longer than the duration of the flashes, as I conceive, from two causes; first, for that those flashes that are farther distant, have their thunder a longer time in passing to the ear, than those which are nearer; because that, though the motion be almost instantaneous, yet the motion requires a sensible time to pass a sensible space, and the times are proportionably longer, as the spaces passed are greater. But a second cause of the duration of thunder, I imagine, proceeds from echoes that are rebounded, both from parts of the earth, and parts of the air, as from charged clouds; of both which I am sensibly assured, having observed the same effects produced by the echoing and rebounding of the sound of a piece of ordnance. But thirdly, we have also the power and violence of the force of the fire and expansion, in firing several combustibles, in suddenly melting of metals and other materials, otherwise difficult and slow enough to be made to flow; in rending, tearing throwing down, and destroying whatever stands in its way, &c. and yet after all, that which causes these, and many other strange effects resembling those of gun-powder, seems to be nothing but a vapour or steam, mixed with the body of the air, which is kindled, not by any active fire, but by a kind of fermentation, or inward working of the

said

saïd vapour. Again, we find that the *Pulvis Fulminans*, as 'tis called, which has some of its materials differing from that of common powder; as also *Aurum Fulminans*, which differs still more, both as to its materials, and its way of kindling, have yet most of the same effects with gun-powder, both as to the flashing and thundering noise, and as to the force and violence: so that these are differing in many particulars, and yet produce much the same effects; whence 'tis probable, that what is the cause of earthquakes, and subterraneous thundring, lightning, and violent expansion, as I may so call those phænomena observable in those crises of nature, may be in divers particulars, different from every one of these, both as to the materials, and the form and manner of accension; and yet, as to the effects, they may be very analogous and similar: so that 'tis but one operation in nature, and that which causes the effect in one causes the effect in all the rest; the outward appearances of the different materials, and the differing way of operating, being nothing but their different modes of acting their several parts, which, when they have done, they are at an end, and there must be a new set of actors to do the same thing again. So the materials that make the subterraneous fire, flame, or expansion, call it by which name you please, is consumed and converted into another substance, unfit to produce any more the same effect; and if the conflagration be so great as to consume all the present store, you may safely conclude that place will no more be troubled with such effects; but if there be left relicts, either already

ready fit and prepared, though sheltered from accension, by some interposing incombustible materials, or that there be other parts not thoroughly ripe and sufficiently prepared for such accension, then a concurrence of after causes may repeat the same effects, and that *toties quoties*, 'till all the mine be exhausted; which I look upon both possible and probable, nay necessary, because I find it to be the general method of nature, always to be going forward in a progress of changing all things from the state in which it finds them. All things, as they proceed to their perfection, so they proceed also to their dissolution and corruption, as to their former state; and where nature repeats the process, 'tis always on a new individual.

Now tho' it may be objected of the material production of lightning, that notwithstanding it seems to be all kindled and burnt off by the flash, yet after some time the same is again renewed, and so from time to time; and therefore as one operation destroys and consumes it, so another generates and reproduces it, and thence it seems probable that the same may be done in the subterraneous regions, so that there would be little reason to suppose that former earthquakes should have been greater than those observed in the present age: I would answer, that tho' it seems plain that the matter of lightning is renewed, yet I conceive that to be only by new emanations from the proper minerals in the bowels of the earth, and not because the same substance burnt off in the lightning, is again restored to its former state, and fitted for a second accension; for though a previous digestion of the
streams

steams may be necessary, yet that only prepares it, but it must be some proper mineral that must furnish the materials. And the same is more evident in vulcano's, which are there only observed to break forth where there is plenty of brimstone and other combustible substances; for were it only a continual new generation of materials for fire, then I see no reason why those *incendiums* should not be equally frequent and great in all places. It follows therefore, that it must be caused, not by the renovation of the fuel, but from the duration of the mines or minerals that supply fit materials, and consequently, that when those shall be quite consumed, then, and not till then, will the fire go quite out. Nay, that there are some such instances of preceding vulcano's, which have heretofore burned, and are now quite spent, may be concluded from the *Pike of Teneriffe*, which seems to carry the strongest evidence of having been formerly a burning mountain; and the island of *Ascension* seems to be another such instance. All which conflagrations are the several symptoms of the progress of nature in her determined course and method.

I cannot therefore perceive any absurdity in thinking or asserting, that this globe of the earth is in a state of progression from one degree of perfection to another, in as much as it is the progress of nature; and at the same time that it may be conceived in a state of corruption and dissolution, in as much as it is continually changed from its preceding state to a new one, which may be, upon some accounts, considered as more perfect, tho' upon

upon others it may be reckoned corrupting, and tending to its final dissolution; and as 'tis most certain that it is continually older in respect of time and duration, so I conceive also that it grows older, as to its constitution and powers; and that there have been many more effects produced by it in its more juvenile state, than it can now produce in its more senile, particularly as to earthquakes and eruptions; for to me it seems beyond a doubt that there have been in preceding ages many of these which have infinitely surpass'd any of later years, or indeed all that we have any certain account of in history. A notice of some ancient traditions concerning a very great one, seems to be preserved in the mythological history of *Phaeton*; of which *Plato* also tells us, that the *Ægyptians* had a more perfect account, than ever the *Greeks* were masters of, who, at best, as to histories of preceding ages, were by the priests of *Egypt* accounted boys and children. In which case we are to distinguish between histories of matters of fact, and those of opinion; and *Plato* hints as much in mentioning the relation. The matters of fact seem to have been the conflagration of many parts of the earth at once, and those the most eminent, such as the mountains, it being probable that this was the time of their production. We are not to conclude that such huge mountains as the *Andes*, *Caucasus*, *Atlas*, &c. could never be produced by means of earthquakes and eruptions, because we do not now find instances of effects of the same grandeur, in this age, or in others of which we have some tolerable account; since in remoter times there has been
much

much greater plenty of proper minerals, which were then consumed, and whose relicts are now but small, and probably not so apt for conflagration, nor so strong in their operations; besides many that were left, may have been since petrified, or converted into other substances, wholly unfit for the foment or fuel of such kinds of fires.

Petrification is a symptom of very old age, as plenty of spirituous, unctuous and combustible or inflammable juices and moisture is a sign of youth. Fluidity is an inseparable concomitant of what we call spirituous substances; and 'tis the plenty of those that makes both plants and animals to flourish in their youthful state, and the consumption and lack of them that make them decay and grow old, stiff, dry, rough, and shriveled; all which marks may plainly be discovered also in the body of the earth; and I am apt to think would be much more evident, if we could be truly informed of the younger condition thereof: I have very good reason to believe that times have been when it had a much smoother, softer and succous skin than now; when it abounded more with spirituous substances, when all its powers were strong and vegete, without any of its present scars, asperities and stiffness: and tho' some may possibly think all these conceptions groundless, and merely conjectural, yet I may in good time manifest, that there are other ways of coming at the discovery of many truths, than what have been hitherto made use of to this purpose, which yet are not less capable of proof and confirmation, than histories and records are from coins, inscriptions or monuments.

To conclude. The assertion of the earth's growing old, cannot be looked upon either as a heterodoxical, or a schismatical one: the kingly prophet has an expression which does plainly declare it, not only of the earth, but of the heavens too^r. “Of old hast thou laid the foundations of the earth, and the heavens are the work of thy hands; they shall perish, but thou shalt endure, yea all of them shall wax old like a garment, as a vesture shalt thou change them, and they shall be changed.” Which expression is almost verbally repeated by the prophet *Isaiab*^f. “Lift up your eyes to heaven, and look upon the earth beneath; for the heavens shall vanish away like smoke, and the earth shall wax old like a garment.” Nay this expression of the psalmist is again *verbatim* repeated by the apostle to the *Hebrews*^t. “And thou Lord in the beginning hast laid the foundation of the earth, and the heavens are the work of thine hands: they shall perish, but thou remainest; and they all shall wax old as doth a garment; and as a vesture shalt thou fold them up; and they shall be changed.” By all which it is evident at least, that *David*, *Isaiab*, and *St. Paul*, were all of this belief. I could produce many expressions to the like purpose, both in sacred and prophane histories of christian and heathen writers, but those I have quoted I suppose may be sufficient to answer such objectors.

^r Psalm cii. v. 25, 26.
v. 10, 11, 12.

^f Chap. li. v. 6.

^t Chap. i.



EARTHQUAKES

Caused by some accidental obstruction
of a continual subterranean Heat.

I Suppose that the subterranean heat or fire, which is continually elevating water out of the abyfs to furnish the earth with rain, dew, springs and rivers, when it is stopped in any part of the earth, and so diverted from its ordinary course by some accidental glut, or obstruction in the pores or passages thro' which it used to ascend to the surface, becomes by this means preternaturally assembled, in a greater quantity than usual, into one place; and therefore causes a great rarefaction and intumescence of the water of the abyfs, putting it into very great commotions and disorders; and at the same time making the like effort on the earth, which is expanded upon the face of the abyfs; and that this occasions that agitation and concussion of it, which we call an earthquake.

That this effort is in some earthquakes so vehement, that it splits and tears the earth, making cracks and chasms in it some miles in length, which open at the instant of the shock, and close again in the intervals betwixt them; nay, 'tis sometimes so extreamly violent, that it plainly forces

the superincumbent strata; breaks them all throughout, and thereby perfectly undermines and ruins the foundation of them; so that these failing, the whole tract, as soon as ever the shock is over, sinks down to rights into the abyfs underneath, and is swallowed up by it, the water thereof immediately rising up, and forming a lake in the place where the said tract before was.

That several considerable tracts of land, and some with cities and towns standing upon them; as also whole mountains, many of them very large, and of great height, have been thus totally swallow'd up.

That this effort being made in all directions indifferently; upwards, downwards, and on every side; the fire dilating and expanding on all hands, and endeavouring proportionably to the quantity and strength of it, to get room, and make its way through all obstacles, falls as foul upon the water of the abyfs beneath, as upon the earth above, forcing it forth which way soever it can find vent or passage, as well through its ordinary exits, wells, springs, and the outlets of rivers; as thro' the chasms then newly open'd; through the *camini* or spiracles of *Ætna*, or other near vulcano's; and those *hiatus* at the bottom of the sea, whereby the abyfs below opens into it, and communicates with it.

That as the water resident in the abyfs, is in all parts of it, stored with a considerable quantity of heat, and more especially in those where these extraordinary aggregations of this fire happen, so likewise is the water which is thus forced out of it;

it; infomuch, that when thrown forth, and mixed with the waters of wells, of springs, of rivers, and the sea, it renders them very sensibly hot.

That it is usually expelled forth in vast quantities, and with great impetuosity, infomuch that it hath been seen to spout out of deep wells, and fly forth at the tops of them, upon the face of the ground; with like rapidity comes it out of the sources of rivers, filling them so of a sudden, as to make them run over their banks, and overflow their neighbouring territories, without so much as one drop of rain falling into them, or any other concurrent water to raise and augment them.

That it spews out of the chafms, opened by the earthquake in great abundance; mounting up in mighty streams to an incredible height in the air, and this oftentimes at many miles distance from any sea.

That it likewise flies forth of the volcano's in vast floods, and with wonderful violence: that 'tis forced through the *hiatus's*, at the bottom of the sea, with such vehemence, that it puts the sea immediately into the most horrible disorder and perturbation imaginable, even when there is not the least breath of wind stirring, but all till then calm and still; making it rage and roar with a most hideous and amazing noise, raising its surface into prodigious waves, and tossing and rowling them about in a very strange and furious manner; over-setting ships in the harbours, and sinking them to the bottom, with many other like outrages.

That 'tis refunded out of these hiatus's in such quantity also, that it makes a vast addition to the

water of the sea; raising it many fathoms higher than ever it flows in the highest tides, so as to pour it forth far beyond its usual bounds, and make it overwhelm the adjacent country; by this means ruining and destroying towns and cities, drowning both men and cattle; breaking the cables of ships, driving them from their anchors, bearing them along with the inundation several miles up into the country, and there running them aground; stranding whales likewise, and other great fishes, and leaving them, at its return, upon dry land.

That these phænomena are not new, or peculiar to the earthquakes which have happen'd in our times, but have been observed in all ages, and particularly these exorbitant commotions of the water of the globe.

This we may learn abundantly from the histories of former times; and 'twas for this reason that many of the ancients concluded rightly enough, that they were caused by the impulses and fluctuation of water in the bowels of the earth; and therefore they frequently called *Neptune*, Σεισίχθων, as also, Ἐνοσίχθων Ἐνοσίγαιος, and Τινάκτορογαίης; by all which epithets they denoted his power of shaking the earth.

They supposed that he presided over all water whatever, as well as that within the earth, as the sea, and the rest upon it; and that the earth was supported by water, its foundations being laid thereon; on which account it was that they bestowed upon him that cognomen Γαίηος, or supporter.

porter of the earth, and that of Θεμελιῶχος, or the sustainer of its foundations.

They likewise believed, that he having a full sway and command over the water, had power to still and compose it, as well as to move and disturb it, and the earth, by means of it; and therefore they also gave him the name of Ασφελις, or, the establisser; under which name several temples were consecrated to him, and sacrifices offered, whenever an earthquake happened, to pacify and appease him; requesting that he would allay the commotions of the water, secure the foundations of the earth, and put an end to the earthquake.

That the fire itself, which being thus assembled and pent up, is the cause of all these perturbations, makes its own way also forth, by what passages soever it can get vent; through the spiracles of the next volcano's, through the cracks and openings of the earth abovementioned, through the apertures of springs, especially those of the *thermæ*, or any other way that it can either find or make; and being thus discharged, the earthquake ceaseth, till the cause returns again, and a fresh collection of this fire commits the same outrages as before.

That there is sometimes in commotion, a portion of the abyss of that vast extent, as to shake the earth incumbent upon it, for so very large a part of the globe together, that the shock is felt the same minute precisely, in countries that are many hundreds of miles distant from each other; and this, even tho' they happen to be parted by the sea lying betwixt them; there wants not instances of such an universal concussion of the whole

globe, as must needs imply an agitation of the whole abyfs.

That though the abyfs be liable to these commotions in all parts of it, and therefore no country can be wholly exempted from the effects of them; yet these effects are no where very remarkable, nor are there usually any great damages done by earthquakes, except only in those countries which are mountainous and consequently stony, and cavernous underneath, and especially where the disposition of the *strata* is such, that those caverns open into the abyfs, and so freely admit and entertain the fire, which assembling therein, is the cause of the shock; it naturally steering its course that way where it finds the readiest reception, which is towards those caverns, this being indeed much the cause of damps in mines. Besides, that those parts of the earth which abound with *strata* of stone, or marble, making the strongest opposition to this effort, are the most furiously shattered, and suffer much more by it than those which consist of gravel, sand, and the like laxer matter, which more easily give way, and make not so great resistance; an event observable not only in this, but all other explosions whatever.

But above all, those countries which yield great store of sulphur and nitre, are by far the most injured and incommoded by earthquakes; those minerals constituting in the earth, a kind of natural gun-powder, which taking fire upon this assembly, and approach of it, occasions that murmuring noise, that subterranean thunder, which is heard rumbling in the bowels of the earth during
earth-

earthquakes, and by the assistance of its explosive power, renders the shock much greater, so as sometimes to make miserable havock and destruction.

And 'tis for this reason, that *Italy, Sicily, Anatolia*, and some parts of *Greece*, have been so long, and so often alarm'd and harass'd by earthquakes; these countries being all mountainous and cavernous, abounding with stone and marble, and affording sulphur and nitre in great plenty.

That *Ætna, Vesuvius, Hecla*, and the other volcano's, are only so many spiracles, serving for the discharge of this subterranean fire, when 'tis thus preternaturally assembled. That where there happens to be such a structure, and conformation of the interior parts of the earth, as that the fire may pass freely and without impediment, from the caverns wherein it assembles unto those spiracles, it then readily and easily gets out, from time to time, without shaking or disturbing the earth; but where such communication is wanting, or passages not sufficiently large and open, so that it cannot come at the said spiracles without first forcing and removing all obstacles, it heaves up, and shocks the earth, with greater or lesser impetuosity, according as the quantity of fire thus assembled is greater or less, till it hath made its way to the mouth of the volcano; where it rusheth forth sometimes in mighty flames, with great velocity, and a terrible bellowing noise.

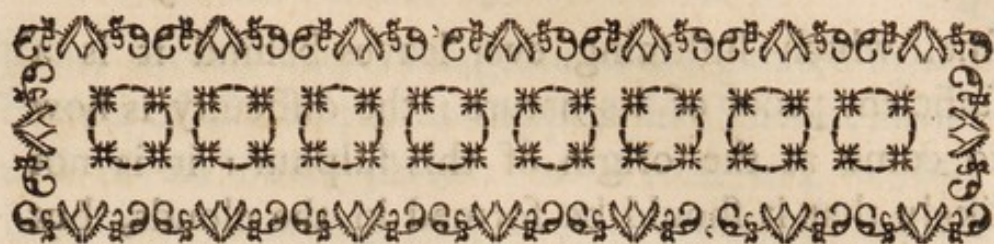
That therefore, there are scarcely any countries that are much annoy'd with earthquakes, that have not one of these fiery vents, and these are con-

stantly all in flames when any earthquake happens, they disgorging that fire, which whilst underneath, was the cause of the disaster; and were it not for these diverticula, whereby it gains an exit, 'twould rage in the bowels of the earth much more furiously, and make greater havock than now it doth.

So that tho' those countries, where there are such volcano's, are usually more or less troubled with earthquakes; yet were these volcano's wanting, they would be more troubled with them, than now they are; yea, in all probability, to that degree, as to render the earth for a vast space around them, perfectly uninhabitable.

In one word, so beneficial are these to the territories where they are, that there do not want instances of some which have been rescued and wholly delivered from earthquakes by the breaking forth of a new volcano there; this continually discharging that matter, which being till then barricado'd up, and imprisoned in the bowels of the earth, was the occasion of very great and frequent calamities.

That most of those spiracles perpetually, and at all seasons send forth fire, more or less; and tho' it be sometimes so little, that the eye cannot discern it; yet, even then, by a nearer approach of the body, may be discovered a copious and very sensible heat continually issuing out.



A

PHYSICO-CHYMICAL EXPLANATION

O F

Subterraneous Fires, Earthquakes, &c.

MY intention is to give, by the means of a chymical operation, a sensible idea of what is transacted in the clouds when they are burst open during a tempest, so as to produce lightning and thunder : but before I come to the experiment, it will be proper to say something of the matter which is immediately concern'd in causing such violent effects, and to examine into its nature and origin.

It cannot reasonably be doubted that the matter of lightning and thunder is a sulphur inflamed and discharged with prodigious rapidity. The sulphury

smell which lightning ever leaves behind it is a sufficient proof of its nature: the difficulty is how to come at the origin of this sulphur: it is not likely that it should be formed in the clouds, but rather that it is brought thither in vapour.

To me it appears that the origin of the matter which produces thunder, is the same as that which causes earthquakes, hurricanes and subterraneous fires, &c. I have explained the cause of these grand commotions in my book of chymistry, on the occasion of a particular preparation of iron called *Saffron of Mars*, which I published several years ago; and having since made several other experiments which serve to confirm what I have there advanced, I am willing to give a succinct account of them all, the first of which is this.

I take a mixture of equal parts of filings of iron and sulphur powdered; this I form into a paste with water, and leave it to digest two or three hours, without fire, in which time it ferments and swells with a considerable heat; the fermentation cracks the paste in divers places, and through the crevices there issue vapours, which indeed are but barely warm if the mass be small, but when it is considerable, as thirty or forty pounds, an actual flame comes forth.

The fermentation accompanied with heat, and even fire, which happens in this operation, proceeds from the penetration and violent friction which the acid points of the sulphur exert upon the particles of the iron.

This single experiment seems, to me, fully sufficient for explaining after what manner fermentations,

tions, shocks and conflagrations are excited in the bowels of the earth, as happens in *Vesuvius*, *Ætna* and divers other places: for if iron and sulphur happen to meet together, and are intimately united and penetrate each other, a violent fermentation must ensue, which will produce fire, as in our operation. But it is easy to prove, that in the mountains I have just now mentioned, there is both sulphur and iron; for after the flames are over a-bundance of sulphur is found on the surface of the earth; and in the passages through which the fire has passed, are discovered substances like those which are separated in our forges.

The following are experiments which I have made since the last edition of my book, and which confirm the former and strengthen my argument.

I put of the same mixture of iron and sulphur in different quantities into tall narrow pots, where I could compress the matter closer than before. Strong fermentations and ignitions ensued, and the matter was rais'd with a degree of violence, and part of it scattered round the pots.

In the summer season I put fifty pounds of the same mixture into a large pot, which I caused to be placed in a hole dug in the earth in a field; it was covered with linen cloth, and with earth over that, about a foot thick. Eight or nine hours afterwards, the earth swelled, grew hot and cracked; then hot sulphury vapours issued forth, and at length flames which widened the crevices, and scatter'd a black and yellow powder about the place: the earth continued hot a good while, which I removed after it was grown cold, and found no-

thing in the pot but a weighty black powder, being the iron filings divested of part of the sulphur: more earth might have been laid over the pot, but that it was suspected that the matter would not kindle for want of air. This operation succeeds better in summer than in winter, on account of the heat of the sun which excites a brisker motion in the particles of the iron and sulphur.

It is then unnecessary to look out any where else for the principle that puts sulphurs in motion in mines, and sets them on fire; their union with iron will produce perfectly this effect, in like manner as it produces it in our operations.

But here offers a difficulty; namely, that these vast subterraneous fermentations and conflagrations cannot have been produced without air: yet it can scarcely be apprehended how air should find a passage to such depths under ground.

To this objection I answer, that there are in the earth great numbers of chinks and passages which are not obvious to our sight, especially in hot countries, where such subterraneous commotions most usually happen: for the great force of the sun-beams heating and calcining, as it were, the earth in divers places, forms crevices in it deep enough for the air to introduce itself.

Earthquakes seem to be occasioned by a vapour, which having been generated in the violent fermentation of iron and sulphur, is converted into a sulphureous blast which forces a passage, and rushes wherever it can, raising and shaking the earth under which it moves. If this sulphureous blast be continually kept confined so as not to be

able to extricate itself through any aperture, the earthquake lasts a considerable time, and with strong plunges, 'till its motion is become languid: but if it procures any passage to escape at, it rushes out impetuously, and creates what is called a hurricane, tossing up the earth, forming abysses, tearing up trees by the roots, oversetting houses; nor can men secure themselves from its fury but by falling flat on their faces and closing their mouths, to save themselves from being carried away, and to avoid breathing the hot suffocating sulphury blast.

Subterraneous fires are owing to the same exhalation; the different effects which it produces arising from several causes; either from the greater abundance of the matter, and consequently the stronger fermentation; or from a greater inlet of air; or from a number of chinks and crevices favouring the escape of the flames, carrying up clouds of ashes along with them sometimes sufficient to cover whole villages, and suffocate or blind the inhabitants.

Ignes fatui, and the lights which appear on waters in hot countries, seem to derive their origin from the same cause; but the sulphureous vapour having been but weak, and its motion impeded in filtering through sand or water, it manifests itself only in a light lambent, spirituous and erratic flame, not having sufficient matter to support it long.

It is very probable that hot mineral waters, as those of *Bourbon*, *Vichi*, *Balarue*, *Aix*, &c. do acquire their warmth from subterraneous fires, or hot sulphury beds over which they glide. For
when

when those waters are left to settle, particles of sulphur precipitate from them, and adhere to the sides and bottoms of their containing vessels.

Those columns of water which are seen sometimes at sea, and threaten sudden destruction to mariners, seem to be owing to these sulphureous winds, driven rapidly up from under the sea, after the like fermentations I have been treating of.

These sulphureous winds which occasion hurricanes, are forced up with so great violence from under ground, that part of them are driven up even into the clouds, which constitutes the materials and cause of thunder: for this wind which contains an exalted sulphur, is entangled among the clouds, and being there beaten backwards and forwards, and strongly compressed, acquires motion sufficient to ignite it, and produce lightning by bursting the cloud and darting itself forthwith with inconceivable rapidity: and this furious motion it is which produces the noise, which we hear, of thunder: for this sulphureous blast issuing violently out from a strait confinement, rudely attacks the contiguous air, and rowls through it with an extraordinary velocity, just as gun-powder out of the cannon wherein it was fired. It may be here said, that a subtile nitre wherewith the air is at all times impregnated, is connected with the sulphur of the thunder, and encreases the force of its motion and action; in like manner as when salt petre has been mixed with common brimstone, it produces a far more violent effect in the rarefaction, than it is capable of by itself.

This

This sulphureous wind of thunder, after rowling some time in the air, slackens its motion; on which account thunder is far more violent and dangerous the moment it is discharged from the cloud, than after it has performed some of its whirlings in the air, being in a very short space reduced to nothing, and leaving only a sulphury stench behind it in the places through which it has pass'd.

As to the thunder stones which the vulgar believes always to accompany lightning, their existence may in my opinion well be questioned, and I verily believe there never was an instance of any such thing: it is not however absolutely impossible, that by a rapid ascent of an hurricane to the clouds there may sometimes be carried up with it some stony or mineral substances, which being softened and melted together by heat, may form what is called a thunder stone: but such stones are not found in places where it thunders; and if any such should be found, it would be more reasonable to believe that it arose from a mineral substance melted and formed by the inflamed sulphur of thunder in the earth itself, than to imagine that it was formed in the air or the clouds, and projected downwards with the thunder.

A difficulty still remains; which is to know how the sulphureous wind, which I have supposed to be the matter of thunder, comes to be kindled among the clouds, which consist of water, and to be there compress'd without being extinguished; for it should seem that the water of the clouds should

should prevent the accension of the sulphur; or at least that it should absorb it when kindled.

To answer this difficulty, I say that sulphur, being a pinguous substance, is not so liable to the impression of water, as other matters are, and that it may be inflamed and burnt in water, like camphire and divers other exaltedly sulphureous bodies. It must needs be, I own, that some part of this sulphur being plunged into the mass of water which constitutes clouds, will be extinguished with a great detonation, like what happens when some solid red hot matter, as iron, is cast into water: this detonation may possibly contribute to the noise of the thunder, but the other more subtile part, and the most dispos'd to motion will be expell'd in a perfect state of ignition. The following experiment will be a proof of my reasoning.

Into a moderate sized matras whose neck had been partly cut off, I put three ounces of good spirit of vitriol, and twelve ounces of common water; having warmed the mixture a little, I threw into it, at several times, an ounce or an ounce and half of iron filings, which produced an ebullition and white vapours; I presented a lighted wax candle to the mouth of the matras, and the vapour instantly took fire with a very loud and violent fulmination; I repeated the application of the candle several times, and fulminations succeeded like the first, during which the matras was often filled with a flame which penetrated and circulated to the very bottom of the liquor, and sometimes the flame lasted a considerable time in the neck of the vessel.

There

There are several remarkable circumstances in this operation. The first ebullition which happens on the throwing in the iron filings, proceeds from the solution of a portion of the iron by the spirit of vitriol; but to render the fumes and the solution the stronger, 'tis necessary to mix water with the spirit of vitriol, in the proportion mentioned; for if the spirit were pure and not diluted, and expanded with water, its points indeed would attack the iron, but they would be so embarrass'd and compress'd together, that they would not have a freedom of motion sufficient to produce any fulmination.

The second is, that the liquor must be warmed a little to excite the points of the dissolvents to penetrate the iron and raise fumes; but it must not be made too hot, for then the fumes would escape too fast, and would only flame in the neck of the matras upon applying the candle, without any fulmination; for that noise arises from the sulphureous part of the matter being kindled quite to the bottom of the matras, and meeting with an obstacle to its rising from the body of the water which it endeavours to escape through.

The third is, that the sulphur which elevates itself in vapour and takes fire, must necessarily arise from the filings of iron alone, since neither the water, nor the spirit of vitriol, especially the stronger sort which I make use of, hold nothing of a sulphureous or inflammable nature, as every one knows: it follows then that the sulphur of the iron filings, having been rarefied and detached
by

by the spirit of vitriol, is exhaled in a vapour extremely susceptible of ignition.

The fourth, that the acid spirits of salt, sulphur and alum produce in this operation, the same effect as spirit of vitriol; but spirit of nitre and aqua fortis excite no fulmination.





O F T H E
VOLCANO's and EARTHQUAKES
I N
P E R U.

IT is a very easy matter to examine the internal disposition of the earth in *Peru*; for the whole province is cut through with *Ravines* or great trenches, many of which are 200 toises or fathoms broad, and sixty or eighty deep, and others twice as much. Some of them may probably have been the work of earthquakes, but the greatest part are owing to rapid torrents of water which among the mountains in tempests are capable of carrying every thing before them, tho' at other times they are so reduced that one may frequently pass them dry-shod. Sometimes the sides of these trenches are cut quite perpendicular, and being pursued to their origin, appear to have been formed by a vertical fall of water.

'Tis only necessary to find out a place proper for descending down this kind of river beds, which seldom hold any quantity of water, in order to survey and examine the qualities of the different *strata* or layers of the earth. None of them discover any considerable marks of great inundations, so frequent in other countries. I have searched them with all possible care for sea shells, but was never able to discover one. Probably the mountains of *Peru* are too high. There is a great quantity of that black sand which the loadstone attracts; it is easy to discern that these layers, whose colours are readily distinguishable, far from being the effect of repeated washings, are an expansion of substances vomited out by volcano's; every thing seems to be the produce of fire. Some of these mountains are formed, to a certain depth, of mere cinders, pumice stones, and fragments of burnt stones of all sizes, all which are sometimes concealed under a bed of common earth, on which herbs and trees flourish. These substances are dispos'd in layers, of different thickness, diminishing as you recede from the mountain, to a foot, half a foot, an inch; but do not quite vanish in less than four or five leagues distance, till approaching another volcano, you begin to meet with them again.

All these particulars I remarked chiefly at the foot of the mountain *Cotopaxi*, which is now become a perfect truncate cone, having lost its head. The base of this volcano has been made round and taken a regular form, from the rowling down of the several materials which were not thrown out
with

with sufficient force, or were of too light a nature to receive any great degree of motion. At the foot are beds of burnt stone reduc'd into small parcels, five or six times a man's height in thickness. The thickest of them all being the uppermost; and I am very sure that this extends also the farthest, and is hid under the good soil, which, 'tis likely, was at first nothing but ashes. I am induced to believe that this upper bed of calcined stones is to be attributed to that terrible eruption which historians speak of, after the death of *Atabualpa*, king of *Quito*, of which we have seen other extraordinary marks with the greatest amazement; stones of eight or nine feet diameter, thrown to more than three leagues distance, several of which by the train they have formed, indicate plainly enough from what volcano they were projected. These massy stones are no ways burnt, like those which cover the foot of the mountain, nor could they have been thrown so far, but at the first effort of the explosion; accordingly 'tis improbable that any like effect will hereafter happen, the mouth of the volcano being at this time 5 or 600 fathoms wide.

The *Indians* pretend that this accident had been foretold them, and that they look'd upon it as the fatal moment when it was in vain to defend themselves longer against strangers who were destin'd to subdue them, and had already made very great advances in their conquest: *Pedro Cieca de Leon*, *Garcilasso*, *Herrera*, and all the historians mention this: they attributed these predictions partly to *Huayana Capuc*, the twelfth and last emperor, father of *Atabualpa*; they called this mountain the volcano

of *Latacunga*, which is five or six leagues distant from it. If we may guess at its different eruptions by the number of the beds of burnt stones at its foot, without taking notice of some of the lowest of them, which are broken and overturned, we must allow this conflagration to have been at least the twentieth; but 'tis probable that each eruption ejects materials of different colours and kinds, and that they are thrown out successively, according to their arrangement in the body of the mountain. However, it is past all doubt that it has raged several times, for the eruption of 1553 could not possibly furnish all those substances which are at this day visible at the foot of this volcano. If all the beds had been elanc'd at the same time, the several settlements which the *Indians* had in that neighbourhood, some of which still subsist, had been infallibly destroyed at once. But what epoch can we assign to those overturned beds which we see below the rest? These had been ranged parallel like the other entire ones; but nature forgetting, as I may say, her gradual way of acting, threw this part of the *Cordiliere* into convulsions. I took particular notice of such broken beds near a place called *Tioupoulou*, above four leagues from the volcano; they are above 40 feet deep: what a prodigious agitation must it have been that was able to break and tumble them one upon another as they now remain?

It was in all probability in times very remote, and most likely before the country was inhabited, that the vast mass of pumice stones about seven leagues south of *Cotopaxi* was formed. There are

no pumice stones to be found on the mountains, but of a moderate size, and all single fragments: but here there are whole rocks of them, consisting of parallel banks each five or six feet thick, and covering more than a league square, to what depth is unknown. Can one imagine what fire it must be that could put this enormous mass in fusion, and that all together at once and in the place where it now actually is? for it is manifest that it never was disturbed, but settled cold on the very spot where it had been melted. The neighbouring parts have profited by this immense quarry, and the whole city of *Latacunga*, which has very fine houses, is built out of it, since the earthquake which destroyed it in 1698.

The last conflagration of *Cotopaxi* in 1742, which happened before our eyes, did no mischief, except by the melting of its snow; notwithstanding that it opened a new mouth in its side about the middle of that part continually covered with snow, whilst the flame constantly issued through the top of the truncate cone. There were two sudden inundations, on the 24th of *June*, and the 9th of *December*, but the last was incomparably the greatest. In the first place it must be noted that the water fell at least 7 or 800 fathoms. The waves it formed in the valley were above sixty feet high, and in some places it rose more than 120 feet. Not to mention the infinite number of cattle which it swept away, it overturned 5 or 600 houses, and destroyed 8 or 900 persons. These waters had 17 or 18 leagues to run, or rather to ravage, towards the south of the *Cordiliere* before

they could get all out of it at the foot of the mountain *Tongouragoua*; yet they took up no more than three hours in all that passage; which may afford some conception of their mean velocity, by which I would understand the mean between the prodigious rapidity they acquired at first by their fall, and their slowest motion afterwards: and if we may judge from the several effects they produced at three or four leagues distance, they must have run 40 or 50 feet in a second of time. Heavy stones of 10 or 12 feet diameter were removed 14 or 15 fathoms from their former places on a plain almost horizontal.

Every body at *Quito* was firmly of opinion, that the water issued from the inside of the mountain, being led to think so, by a whimsical distinction of volcano's throughout all that country, into fiery and watery ones. It is not indeed impossible that waters should be congested in the large cavities which are sometimes formed in the upper parts of mountains, they may be supplied by the ascending steam of the waters below, much in the manner which *Descartes* has explained. If the heat of the sun be insufficient, neighbouring subterraneous fires may furnish a plentiful evaporation; and when the waters are collected above, it is not surprizing that they should sometimes bear down the walls or bounds of their confinement, and at once spread themselves over the country. But no such notion was conceived of what happened at *Cotopaxi*. To prove that the waters boiled in their basin which was formed for them at the top of the mountain, and that it was the vehemence of this ebullition
which

which threw them over the brims, they alledg'd the appearance of the dead corpses below, which almost all looked as if they had been exposed to the action of boiling water.

I got several particulars clear'd up to my satisfaction by examining credible witnesses on the spot. Many who escaped near the edge of the inundation assured me that the water was not in the least hot. They perceived an oily matter which flamed and swam on the surface of the flood and was carried along in the front of it; and probably this was what affected the bodies in such a manner. They likewise told me that when they heard a great noise, which the first fall in all likelihood occasioned, the top of the mountain was surrounded with clouds; which absolutely destroy'd the report of some who gave out that they saw as it were a river run over the brim of the volcano, like water running over the side of an inclined vessel. It appeared to me at length after examining the extent of the space it had covered, and all other circumstances, that a very small quantity of water might cause the whole disaster. In several parts the inundation did not continue a quarter of a minute. It was preceded by a deafening noise. They warned one another of the danger; but many, instead of running to elevated places, went rather to meet it. The water disappeared in an instant; and one would have thought it had been a dream, but for the melancholy monuments it left behind it. I suppose that the snow towards the top of the volcano had been melted some time. That below being out of the influence of the fire retained its hardness,

and formed a sort of basin with the outside of the mountain. But the thaw continually encreasing, the weight was too much to be supported, and so the water fell, and carried down with it large masses of snow, all reeking, which tho' broken by one another in their fall, measured some of them above 15 and 20 feet in thickness.

There was something like this when a furious earthquake threw down the small city of *Latacunga*, with a great many lesser towns and villages as far as *Ambato*, which lie about the middle of our meridian. A very high mountain almost adjacent to the mountain *Chimboraco*, tumbled down, with several lesser ones, upon which issued such a great quantity of water as caused an inundation throughout the neighbourhood, if mouldering earth mixed with water into a mud may be so called; which mud however was so liquid as to run like brooks and rivers, whereof many marks still remain. *Cargaviraco*, the highest of these mountains, has at this time but a moderate height. Others tumbled in part, one half falling, and the other remaining with such a steep acclivity as renders them inaccessible on that side. I had the curiosity to ascend one of them called *Pugnalic*, I found an infinite number of crevices which compell'd me to walk with great caution, and the earth appeared extremely loose. *Cargaviraco*, since it has lost its height, has assumed the figure of a very flat cone, and must contain salts which promote congelation. Although it wants considerably of the height of the level which is taken for the lowest limit of constant snow in the rest of the mountains, yet its top

is covered with perpetual snow. It is very particular in this, that near it you see green fields planted with trees, which extend to the distance of some leagues from it. The fate of *Latacunga* was extremely deplorable. Whole families were buried under the same roof, and there was not a single house that escaped without the death of somebody. This terrible scene was transacted on the 20th of *June* 1698, about an hour after midnight, and almost all the mischief was done by the first shock.

It will not be surprizing that judicial astrology should venture to prognosticate earthquakes in *Peru*. The taste of that vain science prevails in all countries where true knowledge has not made any progress. A curious fellow who was deputy professor of mathematics in the university of *Lima*, published a work in 1729 with the title of *The Dial of Earthquakes*. At that time he was contented with barely pointing out the fatal hours in which there was reason to apprehend a stroke. But in 1734 he published another book containing a *Tragical Period* serving to distinguish the years subject to the same accidents; and he did not scruple to advance that if in 1729 his *dial* had been confirmed by 143 observations, he had now in 1734 collected 70 more equally conformable to it. It has been long ago remarked that maritime places are more exposed to these terrible phænomena than inland countries. Cast your eyes on all parts of the old world where there are any volcano's, and you will find them to be almost all situated in islands or near the sea coast. It is not the *Alpes* for example, that are subject to earthquakes, but those parts of
Italy

Italy which are the most advanced into the *Mediterranean*. The same holds good in *America*. It may sometimes happen that stores of inflammable matters congested in the earth, want nothing but the mixture of water to take fire. But when the sea rises high, whether from the effect of the tides, or being simply accumulated by winds, it may wash over into certain subterraneous canals, and so penetrate into many places which it could not any other ways reach.

From whence it manifestly follows that the several circumstances of the moon's motion which produce any sensible effects with regard to the flux and reflux, may do the like also with regard to earthquakes, and the eruptions of volcano's. Thus an astrologer who is continually prattling about the dragon's head and tail, the moon's distance from the sun, her situation in respect of her apogee and perigee, at the same time, delivering out every thing in a vague manner, as is their constant way, may chance to advance some particulars which will not seem absolutely void of sense. I cannot help thinking the subject worthy of a little consideration: and will venture here in a few words to deliver the result of my own remarks, which come naturally enough into the plan of this relation.

The great number of particular causes which conduce to these terrible accidents, may possibly be one main reason that the concurrence of several such causes, often supplies what is deficient on the part of others: but the particular instant of the effect in point of time, cannot but be very uncertain. The heat of the sun may contribute a share; at least we see

see that it promotes the inflammation of substances which chymistry instructs us to mix together, for representing the conflagration of a volcano^a. The city of *Lima* has been three times ruin'd, first in 1586, and, again in 1687, and in 1746. The first time the earthquake happened *July* the 9th, the two last in *October*, to wit the 19th and 28th, after the equinoctial tides might have introduced a great quantity of water into the subterranean caverns, and the sun advancing into the southern hemisphere, had begun to heat it more. Three other earthquakes were besides very considerable ones; that of *June* 17th 1678, which is no example to our remark, but the other two, that of 1630, and that of 1655, both fell out in *November*, to wit on the 27th and 13th.

So of the six great earthquakes which *Lima* has felt since its foundation, there are four of them which instead of being distributed indifferently through the several parts of the year, have happened in *October* and *November*. This particularity may perhaps be look'd upon as the effect of meer chance. But is it impossible that the return of the heat, and the great tides in *September* and *October*, might contribute thereto? The communication between the subterranean caverns may likewise be a means of the effect of the tides extending itself to a great distance. Among the several earthquakes which I felt myself, one of the most violent threw down some houses near *Latacunga*, and killed several people. At the same time, tho' not precisely at the same instant, close

^a See the tract immediately preceding this.

to a neighbouring mountain, a flame was seen to dart up through the water of a lake. This was in 1736, about the beginning of *December*. I have more observations of the like kind; and all things considered, it appears as fact to me, that tho' the *Peruvians* are exposed to these dreadful phænomena at all seasons, yet are they most subject to them in the last months of the year.

The author I was speaking of, asserts that there is absolutely no critical time except the six hours and some odd minutes that the moon is passing from the horary circle of 3 to that of 9; that is, the time of the reflux, for it is high water on almost all the coasts of *America* in the *South Sea*, when the moon passes the horary circle of 3. But it ought to be well examined into how many different conditions must concur to make our author's rule exact. In the first place it is necessary that the focus of the conflagration should be always in the same place, that the water should follow the same rout, that it should always penetrate with the same velocity, that the mixture should take up precisely the same time in its ignition. If these several conditions do not all take place at once, there must at least be some sort of compensation to supply the defect. The earthquake which occasion'd the destruction of *Lima* in 1746, happened when the moon, instead of passing from the horary circle of 3 to that of 9, was on the contrary, passing from that of 9 to that of 3. The author pretends that no danger is to be apprehended but when the moon's nodes are posited in the malevolent signs of *Scorpio* or *Aquarius*: however at the
time

time of that disaster they were in the signs of *Virgo* and *Pisces*.

Scarce a week passes without some slight shocks and tremblings in *Peru*; if they are not felt in one place, they are in another. For the most part but little attention is given to them; and no body thinks it worth while to register them. An astrologer is therefore at full liberty to boast that the observation never contradicts his prognostick. It is the fatal earthquake alone that can bring his skill in question; but happily those are rare, and may besides happen as well at one time as at another. The precaution is commonly taken not to confine the prognostick within too narrow limits. Moreover the pretended rule can never fail of coinciding with some of the previous accidents or after consequences, and that is enough to save the wizard's credit.

In a word, to proceed methodically, and discover, if there be in reality any such thing as a tragical period, a quite different road must be taken. We must begin with examining the most simple cases; and it seems that eruptions of volcano's should be the first object of observation. But whoever engages in this inquiry must expect to be puzzled with events extremely complicated. Earthquakes may be propagated by the bare contiguity of territories, even to an immense distance from the spot that is directly over the focus of conflagration. In every place are felt all the tremors which are excited round a certain point, and 'tis not to be known to what place they belong particularly; whereas volcano's are determin'd points, and consequently

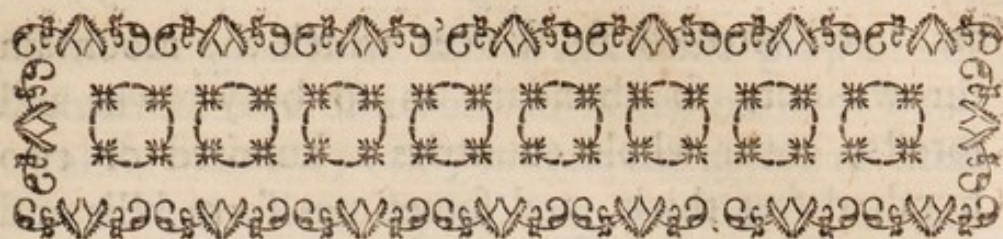
frequently furnish less equivocal observations. There is nothing regular in the return of their ragings. The same should likewise hold good in regard to earthquakes, which for the reason just now assigned, should be still less confined to rules; since generally speaking, they depend on a great number of casualties for any particular place. Rain waters do without doubt very often produce the same effects as the waters of the sea, and it should be noted, that it is in the last months of the year that it rains the most in all the countries I have been speaking of. Sometimes a very strong tremor in the *Cordeliere* extends itself but over an inconsiderable space. There is reason to imagine that the stock of the inflammable matter is then not very deep below the surface, and that the sea has no share in the accident, at least no immediate one. The sea contributes to many earthquakes, as well as the rain to several others; so that there is a two-fold cause of their frequency.

The comparison of the eruptions of volcano's and earthquakes throws some light upon several particulars of these last. The volcano's when in a state of high conflagration, act by fits; the flame and smoak are observed to issue out, almost always, by blasts. When I was employed in one of our stations at *Senegualap*, my sleep was disturbed all night long by the bellowings of the volcano of *Mucas*, called *Sangaï*. I was distant from it something more than 18000 fathoms, yet the noise was horrible and awakened me every moment. This mountain is in the shape of a cone, whose sides are perfectly strait, and it wants only
 2 the

the vertex. All the neighbouring inhabitants are satisfied that the mass of the mountain is continually decreasing. Its present height above the level of the sea is 2664 fathoms. The flame comes out from the top, and frequently a stream of melted matter runs down its sides to the bottom. A *Ravine* of a foot broad has gotten the name of the *Sulphur River*. The bellows of the volcano sometimes form a clashing noise like thunder, but they soon resume their regular period, with a dull noise, with the repetition whereof I was so greatly incommoded. I observed likewise blasts of smoke to issue out of *Cotopaxi* by equal intervals; there was about 42 or 43 seconds between each blast when I observed them. The ignited matter in the bowels of the volcano was doubtless dilated each time: but such dilatation exhausting it in part, the inflammation abated a little; which made room for the external air to enter anew, either by the opening at top, or by some other aperture. Perhaps also there might be at the same time an accession of other inflammable matter, which found at that instant an easy admission. Immediately the conflagration acquired a new force which produced a fresh issue of smoke or another bellowing.

The matters which take fire in the bowels of the earth and cause earthquakes, must be subject to the same alternatives. When the fire is kindled up in an hollow cavern, the dilatation of the inflamed matter and of the air must be extended very far and act in other subterraneous hollows which have a communication with the former. The ceiling of the vault is pushed upwards with
great

great force, and it may be also pushed laterally tho' the stock of the materials be exactly under. The direction of the effort depends then upon the horizontal situation or the inclination of the vault; and this is the cause that sometimes the walls of houses are, or are not spared according to the way they happen to be situated. The ceiling of the vault returns to its former place by repeated oscillations which are independent of the action of the fire; the effort of the explosion ceasing a little, at the same time that the air is over much compress'd in all the neighbouring caverns, whence a violent reflux towards the place of the conflagration, and a new fit and a stronger shock; and thus are brought about the reiterations before mentioned, whose intervals must be sensibly equal, till some very considerable alteration happens either in the subterraneous disposition or in the inflamed materials. The feeblest shocks are those of a soil once shaken, the strongest are those that are the immediate effect of an inflammation; which are analogous to the bellowings of volcano's, and must be repeated with more or less frequency, according to the facility with which the matters are ignited, and likewise according to the proportion of their bulk to the extent of the spaces within which they exert their force.



THE
NATURAL HISTORY
OF
EARTHQUAKES and VOLCANO's.

Burning mountains, called volcano's, contain within them sulphur, bitumen and other materials which are the *pabulum* of a subterraneous fire, whose effect, more violent than that of gun-powder or thunder, has been astonishing in all ages, terrified mankind, and laid the earth desolate. A volcano is a cannon of an immense size, whose aperture is often more than half a league in circumference. Out of this vast mouth are vomited torrents of smoke and flames, rivers of bitumen, sulphur and melted metal, clouds of ashes and stones, and sometimes it ejects enormous masses of rocks to several leagues distance, such as no combined human strength could be capable of putting in motion. The conflagration is so horrible, and the quantity of burning, melted, cal-

cin'd and vitrified substances which the mountain throws out, so abundant as to bury towns and forests, cover whole countries a hundred or two hundred feet thick, and sometimes form hills and mountains, which are no other than heaps of those compacted matters. The action of the fire is so vehement, and the force of the explosion so powerful, as by its reaction to produce shocks sufficient to set the earth in a tremor, agitate the sea, overthrow mountains, destroy cities and the most solid edifices, and that to very considerable distances.

These effects, though natural, have been lookt upon as prodigies, and notwithstanding we behold in miniature, effects of fire pretty similar to those of volcano's; yet the grand, of what nature soever it be, has so irresistible a power of amazing, that I am not surprized some writers have taken these mountains for spiracles of central fire, and the vulgar for the mouths of hell. Astonishment begets fear, and fear generates superstition. The inhabitants of the isle of *Iceland* do believe the bellowings of their volcano to be the cries of the damned, and that it's eruptions are the effects of the fury and despair of its wretched prisoners.

All this however is no more than noise, fire and smoak. There are in mountains veins of sulphur, bitumen and other inflammable materials, and at the same time there are minerals, as pyrites, capable of fermenting, and which this in reality does whenever it is expos'd to air or moisture; it abounds every where in vast quantities, kindles and produces an explosion in proportion to the quantity of the inflamed substances, the effects of
 2 which

which are greater or less in the same proportion: such is the idea of a volcano in the mind of a naturalist, who may easily imitate the nature of those subterranean fires, by mixing together a certain quantity of sulphur and filings of iron, and burying them under ground. Thus will a small volcano be produced, whose effects are the same, regard being had to proportion, as those of great ones, for it ignites by mere fermentation, throws off the earth and stones which cover it, smoaks, flames and explodes.

In *Europe* there are three noted volcano's, *Ætna* in *Sicily*, *Hecla* in *Iceland*, and *Vesuvius* near *Naples* in *Italy*. *Ætna* has burnt time immemorial, its eruptions are very violent, and the substances it throws out so copious, that you may dig in them to the depth of 68 feet, where have been found pavements of marble, and the remains of an ancient city which was covered and buried under that prodigious bed of ejected earth, after the like manner as the city of *Heraclea* was covered by matters thrown out of *Vesuvius*. New fiery mouths were formed in *Ætna* in 1650, 1669, and at other times: the flame and smoak of this volcano may be seen as far as *Malta*, which is 60 leagues; smoak is continually arising out of it, and at certain times it vomits out flames and variety of different substances with great impetuosity. In 1537 there was an eruption of this volcano which occasioned an earthquake throughout all *Sicily* for twelve days, and overthrew a great number of houses and edifices; it ceased by the opening of a new mouth of fire which burnt up every thing within five

leagues of the mountain. Ashes were thrown out in such abundance that they were carried even into *Italy*, and ships at a very great distance from the *Sicilian* shore were incommoded by them.

This volcano has at present two principal mouths, one narrower than the other; these two openings always smook, but no fire is perceived except in the times of the eruption: it is said that stones have been projected out of it to the distance of 60,000 paces,

In 1693, there happened a terrible earthquake in *Sicily* occasioned by a violent eruption of the volcano, which entirely destroyed the city of *Catanea*, and killed above 60,000 persons in that place only, besides great numbers in the neighbouring towns and villages.

Hecla shoots forth its fires through the ice and snow of a frozen soil; and yet its eruptions are no less violent than those of *Ætna*, and other volcano's of the more southern climes. It throws out vast quantities of ashes and pumice stones, and at some times boiling water; there is no dwelling within six leagues of this volcano. The whole isle of *Iceland* abounds in sulphur. The history of its most violent eruptions may be found in a book written by *Dithmar Bleffken*.

Mount *Vesuvius*, according to the account of historians, has not always burned, nor did it begin to do so before the seventh consulate of *Titus Vespasian* and *Flavius Domitian*^a. As soon as the summit

^a It is however a point not settled among the learned, whether this great eruption was the first of that nature, or if

mit was opened the volcano threw out stones and rocks, and afterwards fire and flames in such abundance that they burnt two neighbouring cities, and so thick a smoak that it darkened the light of the sun. *Pliny* the elder ventured to take too near a view of it, and was suffocated with its fumes^b. *Dion Cassius* relates that this eruption of *Vesuvius* was so violent as to throw out ashes and smoak with that violence as to carry them to *Rome*, and even across the *Mediterranean* into *Egypt*. One of the two cities that were overwhelmed with the rejected matter of its first conflagration was *Heraclea*, rediscovered of late years at 60 feet depth under the said matter, whose surface in process of time was become arable, and accordingly cultivated. The relation of the discovery of *Heraclea* is in every ones hands, it were only to be desired that some body well versed in natural history, would be at the pains of carefully examining the several substances which compose this immense thickness, and at the same time note the disposition and situation of them, the alterations that they have produced, or suffered themselves, the direction which they followed, and the degree of hardness they have acquired, &c.

if somewhat of the like kind had not happened in ancient ages. *M. L'Abbé Bannier* has taken some pains about this particular, and has found in *Strabo* and *Diodorus Siculus*, that there is mention of very ancient vestiges of the flames of *Vesuvius*. To these the Abbé adds the authority of several poets, and upon the whole, concludes that there had been fiery eruptions from that mountain in very remote times. *J. B.*

^b See the younger *Pliny's* epistle to *Tacitus*.

There is some ground to believe that *Naples* is situated on a hollow bed of roasted minerals, seeing *Vesuvius* and the *Solfatara* do appear to have internal communications. For when *Vesuvius* burns, the *Solfatara* throws out flames, and when that ceases, the *Solfatara* does so too. The city is situated nearly at an equal distance between them.

One of the last and most violent eruptions of *Vesuvius*, was that of the year 1737, when the mountain vomited a large torrent of red hot and melted metalline substances through several mouths, which spread over the country, and made its way even into the sea. M. de Montealegro, who communicated the relation to the academy of sciences, saw with horror one of these rivers of fire, and observed that its course was six or seven miles from its source to the sea, its breadth being 50 or 60 paces, its depth 25 or 30 palms, and in some hollows of the valleys, more than 120 palms. The matter as it roll'd along look'd like a skum which runs out of the furnace of a forge, &c. °.

In *Asia*, more especially in the islands of the *Indian* ocean, there is a great number of volcano's, one of the most famous of which is mount *Albours*, near mount *Taurus*, eight leagues from *Herat*. Its top is continually smoaking, and it frequently throws out flames and other substances so abundantly, that the whole country round is covered with them. In the island of *Ternate* there is a volcano, which ejects a substance like pumice stone in immense quantities. Some travellers affirm that this volcano burns more furiously about the time

° *Hist. de l'Acad. ann. 1737. p. 7 and 8.*

of the equinoxes, than in other seasons of the year, because certain winds do then blow which contribute to ignite the matter which has so many years nourished its fires^d. The isle of *Ternate* is but seven leagues round, being no other than the summit of a mountain. From the shore you ascend every way towards the middle of the island where the volcano is elevated to a very considerable height, and is in a manner inaccessible. It furnishes several springs of fresh water which run down its sides; and when the air is calm, and the season mild, the gulph is in a less agitation than when the winds are violent^e. This proves that the fire of volcano's does not come from any great depth within the mountain, but from its upper part, or at least, not far down, and that the focus of the conflagration cannot be a great way from the top; for if it were not so, great winds could not contribute to their rage. There are some other volcano's among the *Molucca* islands. In one of the *Mauritian* islands, about 20 leagues from the *Molucca's*, there is a volcano as violent in its effects as that of *Ternate*. The island of *Sorca*, one of the *Molucca's*, was once inhabited; in the middle of it was a volcano, being a very high mountain. In 1693 this volcano vomited out bitumen and other inflamed substances, in so great a quantity as to form a burning lake, which extended by degrees till it entirely covered the whole island^f. In *Japan* are also several volcano's; and in the neighbouring isles navigators have taken notice of many mountains

^d Voyages d'*Argensola*, tom. i. p. 21. ^e Voyage de *Schouten*. ^f *Philos. Transact.* abridg'd, vol. ii. p. 391.

whose tops cast up flames in the night and smoak in the day. There are also several burning mountains in the *Philippine* islands. One of the most famous volcano's of the *Indian* ocean, and at the same time one of the newest, is near the town of *Panarucan* in the island of *Java*. It opened in 1586, and there is no account of its having ever burned before that time. In its first eruption it discharged an immense quantity of sulphur, bitumen and stones. The same year the mountain *Gounapi* in the island of *Banda* (whose last conflagration was not above 17 years ago) opened with a most terrible noise, and vomited out rocks and substances of every kind. Besides all these there are other volcano's in the *Indies*, as in *Sumatra*, and in the northern part of *Asia*, beyond the river *Jéniscea*, and the river *Pésida*, but these two last are not very well known.

In *Africa* there is a mountain, or more properly a cavern, called *Beni-guazeval*, near *Fez*, which always casts forth smoak, and sometimes flames. One of the *Cape de Verd* islands, called *Fuego*, is one huge mountain which burns incessantly; this like the rest throws out much ashes and stones, and the *Portugueze* who have several times attempted to settle inhabitants in the island, have been obliged to drop their project, for fear of the effects of the volcano. In the *Canaries* the pike of *Teneriffe* which passes for one of the highest mountains upon earth, throws forth fire, ashes and great stones; from its top run down rivulets of melted sulphur on the south side, through thick beds of snow, which by soon coagulating, forms veins that may be seen at a great distance.

In

In *America* there is a great number of volcano's, especially in the mountains of *Peru* and *Mexico*. That of *Arequipa* is one of the most famous; it oftentimes occasions earthquakes, which are more frequent in *Peru*, than in any part of the known world. The volcano of *Carapa*, and that of *Malaballo*, are according to the relation of travellers, the most considerable after that of *Arequipa*. But there are a great many others of which we have no very exact knowledge.

In *Mexico* are divers volcano's, the most considerable of which are *Popochampeche* and *Popocatepac*, near which latter *Cortez* march'd to *Mexico*, and some of his *Spaniards* ascended to the top and found the mouth of it half a league round. Sulphureous mountains have also been found in *Gua-deloupa*, *Tercera*, and others of the *Azores* islands; and if all the mountains from whence flame or smoak arises, are to be ranked among volcano's, above 60 of them may be reckoned up; those we have said the most of are the remarkable ones, such as will endure no inhabitants about them, and which project stones and minerals to a mighty distance.

The numerous volcano's among the *Cordelieres*, as I have observed, are the occasion of frequent, and almost continual earthquakes, so that no stone buildings in that country are carried higher than the first floor, whatsoever is added above, is of light wood and rushes. In some of these high mountains are found many precipices and large openings, whose sides look black and burnt, as does the precipice of mount *Ararat* in *Armenia*, called
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the *Abyfs*; these abyffes are the mouths of ancient volcano's, now in a state of extinction.

Of late years there happened an earthquake at *Lima*, the effects whereof were most terrible; the city of *Lima* and the port of *Callao* were almost totally overwhelmed by it. The sea covered every edifice with its waves, one tower alone excepted, so that all the inhabitants were drowned: of 25 ships which were at that time in the port, four were carried a league in land; the rest the sea swallowed up. Of the great city of *Lima* there remained only 27 houses standing, multitudes of persons were crushed to death, especially monks and nuns, their buildings being lofty and of solid materials. This disaster happened in the night time in the month of *October* 1746, the shock having lasted a quarter of an hour.

Near the port of *Pisco* in *Peru*, there was formerly a famous city situate on the sea coast, but it was intirely ruin'd and laid waste by the earthquake of the 19th of *October* 1682: for the sea having exceeded its wonted bounds washed it quite away with all its inhabitants.

If we consult historians and travellers, we shall meet with accounts of several earthquakes and eruptions of volcano's, whose effects have been no less terrible than those I have related. *Possidonius*, as cited by *Strabo*^s, relates that there was a city in *Phenicia*, situated near *Sidon*, which was swallowed up by an earthquake; and with it the neighbouring territory, and two thirds of the said city of *Sidon*, and that this effect did not take place sud-

^s Lib. i.

denly, but most of the inhabitants had time enough to escape: that this earthquake extended itself almost over all Syria, and even to the *Cyclades* islands, and to *Eubea*, where the fountains of *Arethusa* stopp'd all at once, and flow'd not again till several days after, and then by new apertures at a considerable distance from the old ones; and that the earthquake did not give over shaking the island in one place or other, till the earth had opened in the valley of *Lepanta*, and thrown out abundance of ignited matter. *Pliny* relates ^h that in the reign of *Tiberius* there happened an earthquake which demolished 12 cities of *Asia*, and in another place ⁱ he speaks of a prodigy occasioned by an earthquake in the following terms: *Factum est semel (quod eundem in Etruscae disciplinae voluminibus inveni) ingens terrarum portentum, Lucio Marco, Sex. Julio Coss. in agro Mutinensi. Namque montes duo inter se concurrerunt crepitu maximo adsultantes, recedentesque, inter eos flamma fumoque in cælum exeunte interdiu; spectante e via Æmilia magnâ equitum Romanorum, familiarumque et viatorum multitudine. Eo concursu villæ omnes elisæ, animalia permulta, quæ intro fuerant, exanimata sunt, &c.* *St. Austin* says ^k that by a great earthquake a 100 towns were overthrown in *Lybia*. In the days of *Trajan* the city of *Antioch*, and a great part of the adjacent country was swallowed up by an earthquake; and in the time of *Justinian*, in 528, that city was a second time destroyed by the same cause, with above 40,000 of its inhabitants; and 60 years after that, in the time of *St. Gregory*, it was visited by a third earth-

^h Lib. i.ⁱ Ibid.^k Lib. ii. de Miraculis. cap. 3.
quake,

quake, with the loss of 60,000 inhabitants. In the reign of *Saladin*, in 1182, most of the cities of *Syria* and of the kingdom of *Jerusalem* were destroyed by the same cause. In *Apulia* and *Calabria*, earthquakes have been more frequent than in any other part of *Europe*. In the pontificate of *Pius II.* all the churches and palaces of *Naples* were thrown down, near 30,000 persons killed, and the inhabitants that remained alive were forced to live in tents till they could get their houses rebuilt. In 1629 there were earthquakes in *Apulia* which destroyed 7000 persons; and in 1638 the city of *St. Euphemia* was swallowed up, and a stinking lake left in its place; *Ragusa* and *Smyrna* were likewise almost destroyed. In 1692 an earthquake extended over *England*, *Holland*, *Flanders*, *Germany* and *France*, but was felt most sensibly along the sea coasts, and near great rivers: it shook at least 2600 square leagues, yet it lasted but two minutes, and the motion was more considerable on mountains than in valleys¹. In 1688 on the 10th of *July*, there was an earthquake at *Smyrna*, which began with a motion from west to east. The castle fell first, its four walls opening and sinking six feet into the sea: this castle, which was an isthmus, is now a real island a 100 paces from the land. The walls which stood east and west are fallen, those that stood north and south still remain. The city, which is ten miles from the castle, was thrown down presently after; there were in several places openings of the earth, from whence subterraneous noises were heard; before

¹ Ray's discourses, p. 272.

night five or six shocks were felt, the first lasted about half a minute. The roads were agitated, the ground in the city sunk two feet, not above a fourth part of the buildings stood, and those chiefly were founded on rocks; they reckon that 15 or 20,000 persons were lost ^m. In 1695 in an earthquake which was felt at *Bologna* in *Italy*, it was particularly remarked, that the waters were troubled the day before ⁿ.

There was a great earthquake at *Tercera* on the fourth of *May* 1614, which in the city of *Angra* overthrew eleven churches and nine chapels, besides private houses; and in the city of *Praya* it was so terrible, that scarce a house was left standing; and on the 16th of *June* 1628, happened a horrible earthquake in the island of *St. Michael*, near the land the sea opened, and an island arose in a place over which there was before 150 fathoms of water, which island was a league and an half long, and above 60 fathoms high ^o.

There was another earthquake in 1591 which began the 26th of *July*, and lasted in the island of *St. Michael* till the 12th of the following month: *Tercera* and *Fayal* were shaken the next day with such violence, that they seemed as though they were turned about, however these dreadful shocks were repeated there but four times, whereas in *St. Michael* they ceased not a moment for 15 days: the islanders having abandoned their houses, which drop'd as they left them, were all that while exposed to the injuries of the air. A whole city

^m *Hist. de l'Acad. des sciences, ann. 1688.* ⁿ *Hist. de l'Acad. ann. 1696.* ^o *Mandello's voyages.*

called *Villa Franca*, was overturned to its foundations, and most of the inhabitants crushed under the ruins. In many places the plains rose up into hills, and in some the mountains sunk or changed their situation. From out of the ground issued a fountain of fresh water, which run four days, and then was dried up at once: besides this there was so violent an agitation in the sea and air, that the horrid sound of it resembled the bellowings of forests of savage beasts; many died of fear. There were no vessels in the harbours which did not undergo the utmost danger; and others which were at anchor, and some under sail 20 leagues off these islands, were yet more roughly dealt with. Earthquakes are common in the *Azores*; 20 years before one happened in the island of *St. Michael*, which overset a very high mountain^P. In the month of *September* 1627, at *Manilla*, an earthquake levell'd one of the two mountains called *Carvallos*, in the province of *Cagayan*; in 1645 the third part of the city was ruined by a like accident, and 300 people perished; the next year, it suffered by another: the old *Indians* say, they were heretofore still more terrible; for which reason they built their houses of wood only; as the *Spaniards* do now above the first story. The number of volcano's in that island confirm what has been said. For at certain times they vomit out flames, shake the earth, and work the several effects which *Pliny* ascribes to those of *Italy*; that is, to shift the beds of rivers, cause the neighbouring seas to retreat, fill all places about them with ashes, and project great stones to

^P Gen. Hist. of Voyages vol. i. p. 325.

a vast distance with a noise lowder than that of ordnance ^q.

In the year 1646 the mountain of the island of *Machian* was split afunder with dreadful cracks and noises, by an earthquake, an accident not rare in that country; such a quantity of fire issued out of the rent, as consumed several negro plantations with their inhabitants: this prodigious aperture was to be seen in 1685, and 'tis very probable that it still subsists, it was called the *Wheel-rut* of *Machian*, because it ran from the top down to the bottom of the mountain like a hollow way ^r.

The history of the *Parisian* academy mentions the earthquakes of *Italy* in 1702 and 1703, in the following manner: the earthquake began in *Italy* in *October* 1702, and continued till *July* 1703; the parts which suffered most, as also where they began, are the city of *Norcia* with its dependencies, in the *Ecclesiastical State*, and the province of *Abruzzio*: these countries are contiguous and situated at the foot of the *Apennine*, on the south side.

These earthquakes were frequently accompanied with frightful noises in the air, and the same noises have also often been heard without any earthquake, the sky being very serene. The earthquake of *February* 2, 1703, the most violent of them all, was accompanied, at *Rome* at least, with very serene weather and calm air; it lasted there half a minute, but at *Aquila*, the capital of the *Abruzzio*, three hours. It destroyed the whole city of *Aquila*,

^q Voyage de Gimelli Careri, p. 129.
Moluccas, vol. iii. p. 318.

^r Conquest of the

buried 5000 persons in the ruins, and committed great ravage round about.

Commonly the oscillations of the earth were from north to south, or nearly so, which was discovered by the vibrating of the chandeliers in churches.

Two openings were made in a field, out of which were thrown a quantity of stones with violence, which covered it all over and render'd it barren; after the stones it threw out, from the same openings, two spouts of water a great deal higher than the tops of the tallest trees, which lasted a quarter of an hour, and inundated all quite to the neighbouring countries: the water was white, like soap-suds, and without any taste.

A mountain near *Sigillo*, a village about 22 miles from *Aquila*, had upon its top a pretty large plain invironed with rocks which were as a wall to it. The earthquake of the second of *February* changed that plain into a gulph of unequal breadth, its greatest diameter being 25 fathoms, and its least 20: the depth of it cannot be measured, and has been found to exceed 300 fathoms. At the time this opening was formed, flames were observed to issue out, and after them a very thick smoak which lasted three days with some interruptions.

At *Genoa* on the first and second of *July*, they had two small tremors, the last only felt by people on the mole. At the same time the sea in the port sunk six feet, so that the galleys touched ground, and this shallow lasted near a quarter of an hour.

The

The fulphury water in the road from *Rome* to *Tivoli*, diminished two feet and a half in depth, both in the basin and the canal. In several places of the plain called *Testine*, there were springs and brooks which had made it all marshy, but now it is perfectly dry. The water of the lake called *Enfer*, likewise diminished three feet in depth: in the place of ancient springs now dried up, new ones have burst out about a mile from the former, so that in all probability they are the same waters, which have alter'd their course^f.

The earthquake which formed the *Monte di Cenero* near *Puzzoli* in 1538, filled the *Lucrine* lake at the same time with stones, earth and ashes, so that the lake is now a marshy soil^g.

Some earthquakes are felt a great distance at sea, Dr. *Shaw* relates^h that in 1724, being on board the *Gazelle*, an *Algerine* ship of 50 guns, they felt such violent shocks one after another, as if the weight of 20 or 30 tons had been let fall from a good height on the ballast. This was in a part of the *Mediterranean* where they had more than 200 fathom water: he adds that others had felt much more considerable earthquakes in other places, and one among the rest 40 leagues to the west of *Lisbon*.

Schouten^w, speaking of an earthquake which happened in the *Molucca's*, says, that the mountains were shaken, and ships that were at anchor in 30 or 40 fathom water, were jerked as if they had ran ashore, or came foul of rocks; that daily experience shews that the same thing happens in the o-

^f *Hist. de l'Acad. ann. 1704. p. 10.* ^g *Ray's Discourses,*
^h *p. 12.* ^w *Travels, p. 303.* ^u *Tom. vi. p. 103.*

cean where no bottom can be found, and that in earthquakes vessels are violently tofs'd on a sudden though the sea be perfectly calm.

Le Gentil ^x speaks of earthquakes whereof himself was witness, in the following terms. “ I have
 “ made some remarks on earthquakes; first, that
 “ half an hour before the tremor, all animals seem
 “ frightned, horses neigh, break their halters, and
 “ run out of the stables, birds are stunned as it
 “ were, and come in a doors, rats and mice come
 “ out of their holes, &c. Secondly, that ships at
 “ anchor suffer such violent agitations, as to seem
 “ to be falling asunder, their guns break loose,
 “ and their masts spring; this is more than I could
 “ have easily believed, had not many unanimous
 “ testimonies convinced me. I know well that the
 “ bottom of the sea is a continuation of the land;
 “ that if this land be shaken, it communicates the
 “ shock to the waters it sustains; but the thing
 “ which I cannot form a conception of, is that ir-
 “ regular motion of a ship whereof all its several
 “ parts do participate, as if the whole vessel were
 “ a part of the earth, and did not swim in a fluid;
 “ whereas I should think she should be liable to no
 “ other motions than those she experiences in a
 “ storm: besides, on the occasion I am speaking
 “ of, the surface of the sea was smooth, almost
 “ without a wave, and the whole agitation must
 “ be wholly internal, as the wind could have no
 “ concern in the earthquake. Thirdly, that if the
 “ cavern of the earth wherein the subterranean fire
 “ is confined, runs north and south, and if a city

^x *Nouveau voyage autour du Monde, tom. i. p. 172, &c.*

“ over

“ over it be situate in a parallel direction thereto,
 “ all the houses will be overthrown; whereas if the
 “ same vein or cavern crosses the town, the da-
 “ mage will be considerably less.”

It happens in countries subject to earthquakes, that whenever a new volcano is formed, the earthquakes cease, and are no more sensibly felt, but in violent eruptions of the volcano, as was observed in the island of *St. Christopher*^y.

The excessive ravages occasioned by earthquakes have induced some naturalists to imagine that the mountains and other inequalities on the surface of the globe, are the mere effects of subterraneous fires, and that all the irregularities we discern over the whole earth, are to be attributed to the violent shocks and subversions which they have produced: *Ray*, for instance, is of this opinion; he believes that all mountains have been formed by earthquakes, or explosions of volcano's, as the *Monte di Cenere*, the new island near *Santorini*, &c. but he has not taken due notice, that the small elevations formed by the eruption of a volcano, or by the action of an earthquake, are not inwardly composed of horizontal strata, as all other mountains are, for by digging into *Monte di Cenere*, there are found calcined stones, pumice stones, ashes, burnt earth and dross of iron, all mingled together like a heap of rubbish. Besides if the great mountains of the earth, as the *Cordilieres*, *Taurus*, the *Alpes*, &c. had been produced by earthquakes and subterraneous fires, the prodigious force requisite to raise those enormous masses, must at the same time

^y *Philos. Trans.* abridged, vol. ii. p. 392.

have destroyed a good part of the surface of the globe, and the effect of the earthquake would have been extremely, nay inconceivably violent, since the most extraordinary earthquakes recorded in history, have not had force enough to raise mountains. There was one, for example, as *Ammianus Marcellinus* reports^z, in the days of *Valentinian* the first, which was felt all over the known world, but it is not said, great as it was, to have raised one mountain.

It must however be own'd that it will appear from calculation, that though an earthquake may be powerful enough to raise a mountain, yet it would not be sufficient to displace the rest of the globe.

For let us suppose for a moment, that the chain of high mountains which traverses *South America* from the point of *Terra Magellanica* to the mountains of *New Grenada* and the *Gulph of Darien*, had been raised all at once by an earthquake, and then let us compute the effect of this explosion. This chain is about 1700 leagues long, and at a mean about 40 leagues broad, including the *Sierras*, or mountains of less elevation than the *Andes*: the surface is about 68,000 square leagues: I suppose the thickness of the matter displac'd by the earthquake to be one league, or that the mean height of these mountains, from the top to the bottom, or rather indeed to the caverns, which in this hypothesis must support them, is but a league, which will be easily granted; then, I say, the force of the explosion or earthquake will have elevated to the height of

^z Lib. xxvi. cap. 14.

a league a quantity of earth equal to 68,000 cubic leagues: but, action being equal to reaction, this explosion will have communicated to the whole globe, the same quantity of motion: now the whole globe is 12,310,523,801 cubic leagues; from whence subtracting 68,000 there remains 12,310,455,801 cubic leagues, whose quantity of motion is equal to that of 68,000 cubic leagues raised one league; whence it appears that the force requisite to have displaced 68,000 cubic leagues, and remove them one league, would not have displaced the rest of the globe a single inch.

There would then be no absolute impossibility that the mountains have been raised by earthquakes, if their internal composition, as well as their external form were not evidently the work of the waters of the sea. The internal is composed of regular and parallel beds, filled with sea shells; the external of a figure whose angles every where correspond; is it credible that so uniform a composition and so regular a form should be produced by irregular shocks and sudden explosions?

But as this opinion has prevailed with several naturalists, and as it seems to me that the nature and effects of earthquakes are not clearly understood, I esteem it necessary to advance some ideas which may serve to throw light on the subject.

The earth having undergone great alterations on its surface, there are even to very considerable depths, holes, caverns, subterraneous rivulets and empty spaces, which sometimes have communications one with another by chinks and guts. Of caverns there are two kinds, the first is produced by

the action of subterraneous fires and volcano's; the action of the fire lifts up, shakes and disperses to a distance whatever matters are over it, and at the same time rends and disfranges those of either side of it, and so forms caverns, grottos, hollows and irregular dens, but these seldom occur but on round high mountains that have volcano's, and this species of caverns produced by the action of fire, are rarer than the caverns of the second kind, which are produced by waters. We have seen that the different strata of which superficial parts of the terrestrial globe consists, are all interrupted by perpendicular fissures of which I shall explain the origin hereafter; the waters of rain and vapours, descending by these, are collected together upon clay, and form springs and brooks; by their natural motions they find out all small cavities and vacuities, and have a constant tendency to form themselves passages, till they procure some egress; carrying along with them at the same time sand, earth, gravel and other substances which they are capable of comminuting, and so gradually, as I may say, paving themselves ways, and forming a kind of little channels or trenches; at length they run out, either on the surface of the earth or into the sea, in the form of springs: the matters they carry off with them leave vacuities, whose extent may probably be very considerable, and these vacuities form grottos and caverns, whose origin, it appears, is very different from that of the caverns produced by earthquakes.

Earthquakes are of two kinds; one of them is occasioned by the action of subterraneous fires and explosions of volcano's, and these are felt but to
small

small distances, and at the time the volcano's are raging, or before their first eruption. When the materials which constitute subterraneous fires begin to ferment, wax hot, and break out into flame, the fire exerts itself *quaquaversum*, or in every direction; and if it cannot naturally meet with vents, it raises the earth and procures itself a passage by dispersing it, and thus produces a volcano, whose effects are reiterated, and subsist in proportion to the quantity of the inflammable materials. If the shock be considerable, a succussion and slight commotion may be all the consequence, at most a gentle earthquake, without the eruption of any volcano. The air generated and rarefied by the subterraneous fire, may likewise find out small apertures to escape at, in which case again, the utmost consequence will be no more than an earthquake without any eruption or volcano: but when the ignited matter is congested in abundance, and pent up by solid and compact substances, a commotion and a volcano will be the consequence. Now these several commotions make but the first species of earthquakes, and can shake no very great space. A very violent eruption of *Ætna*, for example, may excite a tremor all over *Sicily*, but will never extend to 3 or 400 leagues. When any new mouths of fire happen to open in *Vesuvius*, tremors are felt in its neighbourhood, and at *Naples*; yet no such as these ever shook the *Alpes*, or extended to *France*, or other countries remote from *Vesuvius*. The earthquakes produced from the action of volcano's, are confined to a very small space, being properly the effect of the reaction of fire, whereby

they shake the earth, just as a powder magazine when blown up, occasions a shock and a tremor which are felt at many leagues distance.

There is yet another kind of earthquakes, very different as to their effects, and probably their causes too; such are those which are felt to vast distances, and shake a long stretch of ground without the intermediation of any new volcano or eruption. We have examples of earthquakes which were felt at the same time in *England, France, Germany and Hungary*; and such are extended greatly more in length than in breadth, and shock a belt or zone of earth with a greater and less degree of violence in different places, and are almost ever accompanied with a dull noise like that of a very heavy carriage wheeling on with great rapidity.

To apprehend rightly what are the causes of such earthquakes, it must be remembered that all substances which are inflammable and capable of explosion, do, like powder, at the instant of their inflammation, generate a great quantity of air: that air thus generated by fire, is in a state of exceeding great rarefaction, and from its circumstance of compression within the bowels of the earth, must produce most violent effects. Suppose now that at a considerable depth, as a 100 or 200 fathoms, there should happen to be pyrites and other sulphureous matters, and that through the fermentation excited by the filtration of waters, or by any other means, they come to ignite, let us see what will be the consequence. In the first place these matters are not disposed regularly in horizontal strata, as such substances are which have settled from

from the sediment of waters; on the contrary they are in perpendicular fissures, in caverns at the foot of such fissures, and in other places into which waters can penetrate and there act. These matters taking flame, will produce a great quantity of air, whose spring compress'd in a small space, as that of a cavern, will not only shake the ground about it, but will attempt all ways of escaping and being at liberty. The passages which offer, are the cavities and trenches formed by subterraneous waters and rivulets; the rarefied air will be precipitated with violence into every passage that is open to it, and form a furious wind, the noise whereof will be heard on the earth's surface, accompanied with shocks and tremors. This subterraneous wind generated from fire, will extend full as far as the subterraneous caverns or passages reach, and excite a tremor, more or less violent as it is distant from the focus of the conflagration, and meets with passages more or less confined. This motion being propagated lengthwise, the tremor will be so too, and will be felt along the extent of a terrestrial zone; but the air will not be able to produce any eruption or volcano, having found space sufficient to dilate itself in, or because it may have met with some vents to escape by in the form of wind or vapour: now should it even be denied that any subterraneous passages do exist, through which such wind and vapour can be conveyed, it may notwithstanding be easily conceived that in the very place where the first explosion is made, the ground being elevated to a considerable height, it is necessary that whatsoever borders upon
this

this place must be rent, and divided horizontally, and accompany the motion of the first blast, which will be sufficient to procure passages for communicating the motion to a very great distance. This explanation is agreeable to all the phænomena. It is not at the same instant, nor at the same hour that an earthquake is felt in places a 100 or 200 leagues, for example, asunder: there is neither fire nor eruption above from earthquakes extended to so great lengths, and the noise which almost always accompanies them, marks out the progressive motion of the subterraneous wind. What has been advanced may be further confirmed by connecting it with other facts; it is known that mines exhale vapours, independently of the winds produced by the current of waters, blasts of unwholesome and suffocating vapour are frequently met with; it is likewise well known that there are apertures, abysses, and deep lakes which let forth winds at the surface, as the lake of *Boleslaw* in *Bohemia*.

All this being rightly comprehended, I cannot readily discern, how it should be believed that earthquakes can produce mountains, since the very causes of earthquakes themselves are mineral and sulphureous matters which are ordinarily found nowhere but in perpendicular fissures and veins of mountains, and other cavities of the earth, most of which have been produced by waters; that their substances by inflaming, produce but a momentary explosion, and violent winds which follow the tracks of the subterraneous waters; that the duration of earthquakes is, in reality, but momentary on the surface of the earth, and that consequently their

their cause is no other than an explosion, and not a durable conflagration; and lastly, that those earthquakes which shake a large space, and extend to mighty distances, are so far from raising ridges of mountains, that they do not sensibly elevate the surface of the earth, nor form the smallest hill in the whole length of their course.

Earthquakes indeed are by far more frequent in places where there are volcano's, than elsewhere, as in *Sicily* and near *Naples*; 'tis known from observations made at different times, that the most violent earthquakes happen at the time of the eruption of volcano's; but those earthquakes are not such as extend far, nor can they ever produce a chain of mountains.

It has been sometimes observed that the matters ejected out of *Ætna*, after lying cool for several years, and being then moistened by rains, have rekindled, and thrown out flames with an explosion so violent, as even to produce a kind of little earthquake.

In 1669, during a furious eruption of *Ætna*, which began the 11th of *March*, the summit of the mountain sunk considerably, as every one perceived who had seen it before^a, which is a proof that the fire of the volcano's proceeds rather from the summit than from the interior bottom of the mountain. *Borelli* is of the same opinion^b, and says expressly, that "The fire of volcano's comes
" not from the foot nor the center of the moun-

^a *Philos. Trans.* abridg'd, vol. ii. p. 387. ^b *De Incendiis Montis Ætnæ.*

“tain, but on the contrary from the summit, and
 “kindles but at a small depth.”

Mount *Vesuvius* in its eruptions has often ejected a quantity of boiling water. Mr. *Ray*, who is of opinion that the fire of volcano's comes from a very great depth, says that it is sea water which insinuates into the internal caverns of the foot of the mountain, and urges for proof the remarkable dryness of the summit of *Vesuvius*, together with the motion of the sea, which in violent eruptions recedes from the shore; and shrinks to that degree, as sometimes to have left the port of *Naples* in a manner dry: but should these facts be true, they would be no solid proof that the fire of volcano's comes from a very great depth: for the water they throw out is certainly rain water which soaks in through fissures, and is collected in the cavities of the mountain: fresh springs and brooks are seen to run from the summits of volcano's, in the same manner as from other high mountains; and as they are hollow, and have undergone more concussions than other mountains, it is not strange that waters should be deposited in the caverns within them, and that those waters should be rejected, with other substances, during their eruptions. As to the motion of the sea, it arises solely from the shock communicated to its water by the explosion, which must occasion an afflux and reflux, according to different circumstances.

The substances which volcano's reject, issue out most commonly under the form of a torrent of melted minerals, which inundates all places round such mountains: those rivers of liquified matter stretch

stretch to considerable distances, and in cooling, form themselves into horizontal or inclining beds, which as to their position are similar to the beds which are made of the sediments of waters; but it is very easy to distinguish the beds formed by the spreading of substances rejected by volcano's, from those which arise from sediments of the sea.

1st, Because they are not every where of an equal thickness. 2^d, Because they contain no other than such matters as may be evidently perceived to have been calcined, vitrified, or melted. 3^d, Because they do not extend to a very great distance. There being a multitude of volcano's in *Peru*, and the foot of most of the volcano's of the *Cordillieres* covered with matters vomited out of those mountains, it is not surprizing that no sea shells should be found in all that soil, since they have been calcined and destroyed by the action of the fire: but I am persuaded, that were one to dig into the clayey soil, which according to M. *Bouguer*, is the ordinary land of the valley of *Quito*, shells would be met with there, as they are in all other places; supposing that soil to be really of clay, and that it is not formed, as is that at the foot of the mountains, of the excrements of volcano's.

It has been often asked, for what reason are volcano's found in high mountains? I think I have in part satisfy'd this query already elsewhere, however I will not close this subject without explaining myself more particularly.

The pikes or points of mountains were all of them once covered and invironed with sand and earth,

earth, which rain waters afterwards washed down into the valleys, and left nothing but the rocks or stones remaining, which formed the kernel or core of the mountain; this core being laid bare, and stripped to the foot, became after this liable to further injuries from the air, besides the scaling off and separating of many great and small fragments by frost, which rowled down below, several rocks of the summit cleaving asunder from the same cause. Those which formed the base of the summit being uncovered, and no more supported by the surrounding earth, gave way a little, and by separating from each other formed small interstices: this yielding of the lower rocks could not take place without communicating a more considerable motion to the upper ones, whereby they were cleft and rent from one another. In consequence of all this an infinity of perpendicular fissures great and small, came to be wrought in the core of the mountain, from the summit to the base of the lower rocks: through these the rains penetrated, and loosened or dissolved all the minerals and other substances in the heart of the mountain, which they were capable of acting upon; they formed pyrites, sulphurs and other combustible matters; and when in process of time these matters became accumulated in a large quantity, they fermented, took flame and produced explosions and other effects of volcano's. Perhaps too there might be a stock of such mineral substances already formed in the heart of the mountain even before the rains had penetrated, and these might force open fissures, and give passages to the

water and air, which put them into the state of inflammation which produced a volcano. No such motions can be brought about in plains, where all things subsist in a perfect repose, and nothing is capable of being displaced, so that it is not at all strange that they are entirely free from volcano's.

When coal mines are opened, which are usually found in clayey soils at a great depth, it sometimes happens that the beforementioned substances take fire, and there are some mines in *Scotland, Flanders, &c.* which continue burning several years: the communication of the air is sufficient for this effect: but this sort of fire produces but slight explosions, without forming volcano's, because all being solid and compact in such places, no such fires can be wrought up as those are in volcano's, where there are cavities into which the air enters, and by augmenting and assisting the action of the fire, produces the terrible effects we have treated of in this essay.





A

SUMMARY of the CAUSES

OF THE

ALTERATIONS

Which have happened to the Face of
the EARTH.

THE changes and alterations that have been made in the superficial part of the terraqueous globe have been effected chiefly by water, fire and wind. Those by water have been either by the motions of the sea, or by rains; and both either ordinary or extraordinary: the ordinary tides and spring-tides of the sea do wash away the shores, and change sand-banks and the like. The extraordinary and tempestuous motions of the sea, raised by raging and impetuous winds, subterraneous fires, or some other hidden causes, overwhelm islands, open fretum's, throw up huge beds and banks of sand, nay vast baiches (*beaches*) of stone, extending some miles, and drown whole countries. The ordinary rains contribute something

thing to the daily diminution of the mountains, filling up of the valleys, and atterating (*wearing away*) the skirts of the seas. The extraordinary rains causing great floods and deluges, have more visible and remarkable influences upon such mutations, doing that in a few days, which the ordinary weather could not effect, it may be, in an hundred years.

In all these changes the winds have a great interest; the motion of the clouds being wholly owing to them, and in a great measure also the overflowings and inundations of the sea.

Whatever changes have been wrought by earthquakes, thunders, and eruptions of volcano's, are the effects of fire.

All these causes co-operate towards the lowering of mountains, leveling of the earth, straitening and landing up of the sea, and in fine compelling the waters to return upon the dry land, and cover the whole surface of it, as at the first. How to obviate this in a natural way, I know not, unless by a transmutation of the two elements of water and earth one into another, which I can by no means grant. 'Tis true indeed, the rocky parts of the mountains may be so hard and impenetrable, as to resist and hold out against all the assaults of the water, and utmost rage of the sea; but then all the earth and sand being washed from them, nothing, but as it were their skeletons, will remain extant above the waters, and the earth being in effect drowned.

But though I cannot imagine or think upon any natural means to prevent and put a stop to this

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effect,

effect, yet I do not deny that there may be some; and I am the rather inclinable so to think, because the world doth not in any degree proceed so fast towards this period, as the force and agency of all these causes together seem to require. For, as I said before, the oracle predicting the carrying on the shore of *Cilicia* as far as *Cyprus* by the earth and mud that the turbid river *Pyramus* should bring down, and let fall in the interjacent strait, is so far from being filled up, that there hath not any considerable progress been made towards it, so far as I have heard or read, in these 2000 years. And we find by experience, that the longer the world lasts, the fewer concussions and mutations are made in the upper or superficial region of the earth; the parts thereof seeming to tend to a greater quiet and settlement.

Besides the superficies of the sea, notwithstanding the overwhelming and submersion of islands, and the straitening of it about the outlets of rivers; and the earth it washes from the shores subsiding, and elevating the bottom, seems not to be raised higher, nor spread further, or bear any greater proportion to that of the land than it did a 1000 years ago.





SOME CONSIDERATIONS ON THE Causes of EARTHQUAKES.

IN the earthquake which happened the 8th of *March* 1749-50, I being then awake in bed, on a ground-floor, near the church of *St. Martin's in the Fields*, very sensibly felt the bed heave, and consequently the earth must heave too. There was a hollow, 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 to the end of the earthquake, seemed to be about four seconds of time. The soldiers who were upon duty in *St. James's Park*, and others who were then up, saw a blackish cloud, with considerable lightning, just before the earthquake began; it was also very calm weather.

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 are often signs of plenty of inflammable sulphureous matter in the air; such as *ignes fatui* or *jack-a-lanterns*, and the meteors called falling stars.

Now, I have shewn many years since, in the appendix to my *Statical Essays*, experiment 3, p. 280. the effect that the mixture of a pure and a sulphureous air have on each other; viz. by turn-

ing the mouth downwards into a pan of water, of a glass vessel of a capacity sufficient to hold about two quarts, with a neck about 20 inches long, and two inches wide. Then, by putting under it, in a proper glass vessel, with a long narrow neck, a mixture of *aqua fortis*, and powdered *pyrites*, viz. the stone of 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 of the glass 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, then an equal quantity of fresh air will rush in at the mouth of the neck of the vessel, which must be immediately 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 earthquake, during which effervescence, 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 they 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 this after several repeated admissions of fresh air: but after every 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 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 arise from several mineral substances, especially from the *pyrites*, which abounds in many parts of 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 the 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 the vapours are equably and uniformly mixed in the air; as happens also in the effervescences and fermentations of other liquors. The common observation therefore, that lightning cools the air, seems to be grounded 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 va-

pours, which are sometimes raised in plenty, immediately below the clouds? the most dreadful thunders being usually when the air is very black with clouds; it rarely thundering without clouds; clouds serving, in this case, like the abovementioned inverted glasses, as a partition between the pure and sulphureous airs: which must therefore, upon their sudden admixture through 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 of the clouds, more gradually intermixed, by the constant more gradual ascent of the warmer sulphureous vapours from the earth, and the descent of the cold serene air from above. And though there was no luminous flash of light in the glass, yet, where 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 destroying 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 quantity of elastic air; it should therefore cause great commotions and concussions in the air, when the air rushes into those evacuated places; which it must naturally do with great velocity.

Dr. *Papin* has calculated the velocity with which
air

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 feet in an hour: 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^a.

Hence we see that an outrageous hurricane may be caused, by destroying a small portion of the elasticity of the air of any place, in respect to the whole. No wonder then, that such violent commotions of the air should produce hurricanes and thunder-showers; especially in the warmer climates; where both the sulphureous and watery 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 of *Guiney*, called by the sailors the *Ox's Eye*, which are forerunners 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 elastic air, cause the ambient air to rush with great violence into that vacuity, thereby producing tempests and hurricanes; and off the coast of *Guiney* they have sometimes three or four of these hurricanes in a day; the forerunners of which are these black sulphureous clouds, with a serene clear air and calm sea; which on a sudden turns tempestuous, on the explosion of

^a *Phil. Transf. n. 184, p. 195.*

these sulphureous clouds. And in *Jamaica* they never have an earthquake when there is a wind to disperse the sulphureous vapours.

In the 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, as it 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 quantities 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 at first kindled at the surface, and not at great depths, as has been thought: and the explosion of this lightning is the immediate cause of an earthquake.

It is in the like manner that those meteors, which are called falling stars are supposed to be kindled 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 over it at a distance, in the sulphureous inflammable smoke of it.

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

tinually ascending through 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 *Monf. de Buffon* remarks, naturalists have observed perpendicular and oblique clefts, in all kinds of layers of earth, not only among rocks, but also among all kinds of earth, that have not been removed, as is observable wherever the earth is open to any depth. Now these clefts are caused by the drying of the several horizontal layers of the 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 the more.

It is very observable, in the opinion of *Borelli*, and other naturalists, that volcano's begin first to kindle near the surface or top of the mountains, and not in the caverns in the lower parts of the mountains. *Monf. de Buffon* says that earthquakes are most frequent where there are volcano's, sulphureous matter abounding most there: but that, though 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 to take time to extend to the great distances,

tances, 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, as volcano's sometimes do.

The earthquake in *London*, *March* 8, 1749-50, was thought to move from eastward to westward. *M. de Buffon* mentions an earthquake at *Smyrna* in the year 1688, which moved from west to east; viz. because the first kindling probably began on the western side; and in the earthquake at *London* on the eastern side. And accordingly it was observed that the reddish bows in the air, which appeared 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 the earth.

M. 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 fall of the castle walls which ran from east to west, but not those which ran from north to south: A probable argument, that as the freest passage, for the greatest explosions were made in the clefts of the earth which ran east and west; which would make the vibrations north and south.

It was observed that the waters turned foul the day before an earthquake at *Bologna* in *Italy*: and I was informed, that the water of some wells in *London* turned foul at the time of the earthquakes; 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 earth. For if the like motion of a small revolving glass 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 cannon in *St. James's Park* is observed to electrify the glass 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 aerial lightning, which rends oaks in pieces, and has been known to run along and melt an iron bell-wire on two sides of a room, &c. And accordingly it was observed, in the great earthquake at *Jamaica*, that the most tremendous roaring was in the rocky mountains. And in the late earthquake

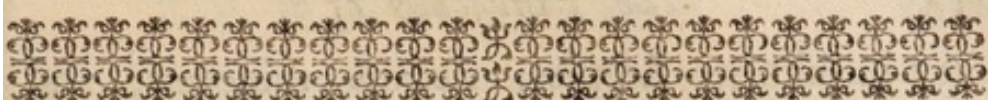
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of

of *March 8* in *London*, the loudest explosions were thought to be heard near such large stone 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 explosion 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 weather-cock, as they rushed off, made so much the louder expansive explosion.





THE
PHILOSOPHY
OF
EARTHQUAKES.

Positions or Circumstances.

I. **T**HAT earthquakes always happen in calm, warm, dry, sultry seasons; or in a dry frosty air.

II. That they are felt at sea, or on lakes, rivers, even in the main ocean, as well as on land: and at that time the sea and waters are calm.

III. That earthquakes differ very much in magnitude. Some shake a very large tract of country, at the same instant of time: sometimes extend to many countries, separated by mountains, lakes, seas, the ocean.

IV. That earthquakes differ much in the quantity of their vibratory motion; whence in some, though largely extended, they are innocuous: in others, both small and large, they lay all in ruins.

V. That a hollow thundering noise accompanies them, or rather seems to precede the shock; which rolls in the air, like the noise of cannon.

VI. That they are felt more sensibly in the upper story of houses, than in the lower. On
lofty

lofty buildings, steeples, *Turkish* minarets, and the like.

VII. That the shock is more violent upon more solid buildings, churches, castles, towers, and stone houses, than on those of slighter materials.

VIII. That many people find themselves sick at stomach, with head-achs, *vertigo's*, pains in their joints, and the like: which sometimes last for the day after, or longer.

IX. That earthquakes generally happen to great towns and cities: and more particularly to those that are situated on the sea, bays, and great rivers.

X. That earthquakes do not cause any damage to springs, and fountains: but the water in wells becomes foul for some time.

XI. That they are frequent in the neighbourhood of a volcano.

XII. That earthquakes often shake rocks, mountains, cliffs hanging over the sea, split them from top to bottom, throw down great parcels of them.

XIII. That fowls domestic, birds in the air, cattle in the fields are affrighted, fishes in the water much affected therewith.

XIV. That chandeliers in churches vibrate, bells in steeples and houses ring.

XV. That sometimes the hollow, thundering noise accompanying an earthquake, is heard without any motion of the earth: at other times accompanies it.

XVI. That fire balls and meteors are frequently observed then.

XVII.

XVII. That the surface of the earth is chiefly, and most frequently the object of earthquakes.

XVIII. That earthquakes affect to run up rivers and sea-shores, and act more violently on places neighbouring thereto.

As to the cause of earthquakes, the moderns have not improved upon the ancients, any farther than by the fancied analogy of some chymical experiments. But these chymical experiments, and all sorts of explosions by gun-powder and the like, are to me a very unsatisfactory solution. They are merely artificial compositions, which can have nothing similar, in the bowels of the earth, and they produce their effects by violence, by rending and tearing, by a *solutio continui*. This indeed is too often the case of earthquakes, but that in a partial degree, not at all equivalent to the compass of the shock; and is very far from being the constant concomitant of an earthquake; quite the contrary. Innumerable such happen where there is no breach of the surface; and in the three or four felt by us of late years, nothing of it has appeared. But the immensity of the vibration of the earth which shook every house in *London*, with impunity, and for twenty miles round, can never, in my apprehension, be owing to so unbridled a cause, as any subterraneous vapours, fermentations, rarefactions, and the like; the vulgar solution. Nor does the kind of motion which I discern in an earthquake, in any sort agree with what we should expect from explosions.

The struggles of subterraneous winds and fires, that should heave up the ground, like animal convulsions, seem to me impossible: Their powers, and manner of acting, if such there be, are quite incapable of producing the appearance of an earthquake. That these should operate instantaneously, in one minute through a circle of 30 or 40 miles diameter, or more, I could not conceive: nor that there should be any possible, much less ready passage through the solid earth, for such nimble agents, as every one is apt to imagine, that speak of this appearance; without sufficiently reflecting on the innumerable difficulties in that *hypothesis*.

We cannot pretend to deny, that there may be such vapours, and fermentations, inflammable substances, and actual fires in the bowels of the earth, and that there may be some caverns underground, as well as we find some few above ground: such as *Pool's Hole*, the *D—l's A—se* in the *Peak of Derbyshire*, and *Okey-Hole* in *Somersetshire*. These, I believe, to have been so from the creation, and never were made by earthquakes. We know there are hot springs running continually: there are some volcano's frequently belching out flames and smoke, and to these perhaps some earthquakes may be owing, though not according to the vulgar notion.

But these matters are very rare, and much rarer than earthquakes, both as to time and place. *Vesuvius* in *Italy*, and in that part of it abounding with mines of sulphur: *Ætna* in *Sicily*, and *Hecla* in *Iceland*; these are all we know of in the old world. In the *Andes* mountains of *America* there

there are some. The scarcity of these appears to me a strong argument against the common deductions made therefrom, as to their being the cause of earthquakes. And further, we cannot possibly think of earthquakes doing their work that way, without absolutely ruining the whole system of springs and fountains, throughout the whole country where they pass. But all this is quite contrary to fact.

These considerations I apply only to this little inconsiderable space of a circle of 30 miles diameter, as with us. But what is that to the earthquakes we read of in history? In the year of our Lord 17, no less than thirteen great and noble cities in *Asia Minor* were destroyed in one night. The compass of this earthquake may be reckoned to take up 300 miles diameter, as a circle. And altogether as great, nay far greater in extent was that most dreadful one of *November 1, 1755*, whereby, as of old the cities of *Asia*, *Lisbon* was destroyed, with several in *Africa*, and a vast number besides nigh totally ruined: yet none of these were swallowed up, but shaken into an heap of rubbish.

From these considerations I cannot persuade myself to enter into the opinion of vapours and eruptions being the cause sought for. If we would consider things like philosophers, let us propose to ourselves this problem: *Where is the power to be placed, that is required to move a surface of Earth, thirty 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 produced in form of an inverted cone; and that a diameter of 30 miles, in the base, will require an axis of 15 or 20 miles to operate upon that base, so as to shake it at least. Now the vapours, or whatever power we propose to operate, according to the foregoing requisite, 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 diameter, whose axis is 20? or, was it possible, would not the whole texture of that body of earth be quite disturbed and shattered; especially in regard to its springs and fountains? but nothing like this is ever found to be the consequence of an earthquake, though fatal to cities.

Apply this reasoning to the earthquake of *Asia minor*; and this vigorous principle at the apex of the cone must lie, at least, 200 miles deep in the ground: enough to shew the absurdity of any moving power placed under the earth! a cone of 300 miles diameter at base, 200 in axis. I dare be bold to say, that all the gun-powder made since its invention, if put together and fired, would not be able to move it: how much less pent up vapours? what must we say of a circle 900 miles diameter?

But could that be admitted as possible; would 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, and that this shall be often repeated without

out the least damage? we may as well imagine, that we can stab a man a hundred times, and never touch vein or artery.

We are then next to inquire: *What is the cause of earthquakes?*

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 through any given distance; when we see, upon a touch, or an approach, between a non-electric and an electric body, what a wonderful vibration is produced! what a snap it gives! how an innocuous flame breaks forth! how violent a shock! is it to be wondered at, that hither we turn our thoughts, for the solution of the prodigious appearance of an earthquake?

Here is at once an assemblage of all those properties and circumstances which we so often see in courses of electricity. Electricity may be called a sort of soul to matter; thought to be an ethereal fire pervading all things; and acting instantaneously, where, and as far as it is excited.

We had lately read at the royal society a very curious discourse from Mr. *Franklin* of *Philadelphia*, concerning thunder-gusts, lightning, the northern lights, and like meteors; all which he rightly solves from the doctrine of electricity. For, if a cloud raised from the sea, which is a non-electric, happens to touch a cloud raised from exhalations of the land, when electrified, it must immediately cause thunder and lightning. The electrical fire flowing from the touch of perhaps a

thousand miles compass of clouds, makes that appearance which we call lightning. The snap which we hear in our electrical experiments, when re-echoed from cloud to cloud, the extent of the firmament, makes that affrightning sound of thunder.

From the same principle I infer, that, if a non-electric cloud discharges its contents upon any part of the earth, when in a high electrified state, an earthquake must necessarily ensue. The snap made upon the contact of many miles compass of solid earth, is that horrible uncouth noise, which we hear upon an earthquake; and the shock is the earthquake itself.

In the relation from *Portsmouth*, and the *Isle of Wight*, concerning the shock of the earthquake on the 18th of *March*, 1749-50, the writer observes, the day was warm and serene; but upon a gentle shower falling in the evening, the earthquake came. Here we have reason to apprehend the electrified state of the earth, and the touch of the non-electric, which caused the earthquake,

The learned Dr. *Childrey* observes, treating on this subject, that earthquakes happen upon rain, in the time of a great drought.

'Tis objected, that, if this were the case, nothing would be more frequent than earthquakes: but these two circumstances concurring, a shower and dry weather must not necessarily cause it, any more than touching a tube before it is electrified causes a snap. The earth must be in a proper electrified state to produce it; and electricity has its fits; is remitted, intended, ceased and re-

recommenced. It has its bounds. All causes must concur: though a shower of rain falling upon the earth, when electrified, may cause an earthquake, yet too much rain before, will prevent that state of electricity necessary.

The day before the catastrophe of *Port Royal*, the weather was remarkably serene and clear. In that most dreadful earthquake of *Sicily*, 1692, where 54 cities and towns, besides a great number of villages, were destroyed, but especially the whole city of *Catanea*; it was preceded by a most agreeable, serene, and warm season, which was the more observable, on account of its being unusual at that time of the year.

I have been informed, that in the mornings of our earthquakes in *February* and *March* 1749-50, the air was serene and calm, and on the morning before that, in *February*, the air was observed to be perfectly calm; and that a little before, a black cloud appeared over great part of the horizon. Dr. *Hales* says the centinels in *St. James's park*, and others who were abroad in the morning of *March* the 8th, observed a large black cloud, and some coruscations, just before the shock; and that it was very calm weather: and that in the history of earthquakes, they generally begin in calm weather, with a black cloud.

We have been acquainted by those who remember it, that in the earthquake of *November* 1703, which happened in *Lincolnshire*, the weather was calm, close, gloomy, warm, and dry; in a degree highly unusual at that season. And thus was it with us all the year 1749, thereby preparing

B. Yet
Damp
must have
prevailed
afterwards
188 Dr. Hales
p. 260

the earth's surface for the electrical stroke, which I have asserted to be the cause of them.

In the account of the great earthquake of *November 1, 1755*, from *Amsterdam*, it was wrote that the weather was calm ; the like from *Berlin*, *Kinsale*, *Gibraltar*, *Lisbon*, &c.

Mr. *Flamsteed* supposes a calm even necessary before an earthquake : And Dr. *Hales* says, that long, dry, hot seasons are usually the preparatory fore-runners of earthquakes.

This observation precludes the suspicion of earthquakes arising from tumults and commotions in the upper, or under region of the air. The remarkable clearness of the air before earthquakes, observed by all, shews evidently how free it is from vapours, or the like.

Agreeable to our fifth position, Mr. *Flamsteed* writes ^a, “ a hollow noise in the air always precedes an earthquake, so near, that it rather seems to accompany it,” this he spoke of that felt in *London 1692*, when the noise was heard by many that lived in the out-streets and alleys, remote from the constant tumult of the great streets ; but in both our latter ones, the whole city heard the noise.

A gentleman of *Hartingfordbury* says, the noise preceded the shock. And this is a common observation, which at once both strengthens our opinion of electricity, and confutes that of subterraneous vapours ; for, in the latter case, the concussion must precede the noise.

^a Letter concerning an Earthquake.

Just before the earthquake of *March* 8, 1749-50 Mr. Secretary *Fox's* shepherd at *Kensington* was surprized with a very extraordinary noise in the air, rolling over his head, as of cannon close by. He likewise thought that it came from the north-west, and went to the south-east; a motion quite contrary to what must have been the case, if it were really cannon. It passed rushing by him, and instantly he saw the ground, a dry and solid spot, wave under him like the face of a river. The trees of the avenue nodded their tops, and were shaken like spears.

In the earthquake of *September* 30, 1750, they were suddenly surprized with an uncommon noise in the air, like the rolling of large carriages in the streets, for about 20 seconds. At the same instant they felt a great shock or snap, which sensibly shook a punch-bowl, and made it ring.

Agreeable to our second position, Mr. *Flamsteed* “ writes ^b, that earthquakes are felt at sea equally
 “ as at land. Our merchants say, that tho’ the
 “ water in the bay of *Smyrna* lies level, and
 “ smooth as a pond, yet ships riding there feel
 “ the shocks very sensibly; but in a very different
 “ manner from the houses at land: For
 “ they heave not, but tremble; their masts
 “ shiver, as if they would fall to pieces, and their
 “ guns start in their carriages, though the surface
 “ of the sea be all the time calm and unmoved.

Dr. *Hooke* tells us ^c, “ that a ship felt a shock
 “ in the main ocean; that the passengers, who

^b Letter concerning an earthquake.

^c *Philos. Collections*, N^o 6. p. 185.

“ had been asleep in their cabins, came upon deck
“ in a fright, fearing the ship had struck upon
“ some rock ; but on heaving the lead, found
“ themselves out of all soundings.”

In the earthquake of the first of *November* 1755, the *Dutch* ships of cape *St. Marys* fired guns of distress, thinking they struck on ground ; and we have received many accounts of ships at sea, in the middle of the ocean, participating in this amazing phenomenon. A very loud thundering noise begins it ; it seems as if casks were rolling about the deck. The masts, the whole ship trembled like a reed shaken with the wind. A great thump felt at the bottom of the ship, as if struck upon a rock. The compass often overturned in the benacle, fire-balls and flashes of lightning seen by night.

All this is extremely agreeable to our assumption. The water receives the electrical touch, and vibratory intestine motion of its parts, as well as land : And the impression may be made solely on the water, a non-electric, by the touch of an electric fire-ball, or the like ; and that seems to have been often the case. The proper vibratory motion is unpressed on the water without ruffling its surface ; and so communicated to all the parts of the ship, gives the sense of a shock to the bottom, the shivering to the mast, and the rest of the symptoms ; which sufficiently proclaim the cause of it to be an electrical impression upon the water. The president of the Royal Society mentioned a relation of a waterman that felt it in his boat upon the river : he thought it like a great thump at the
bottom

bottom of the boat. And so the ships at sea fancy they strike upon a rock.

This makes us apprehend the reason of the fishes leaping out of the canal in *Southwark*, of which we had an account. So, in that of *Oxford* 1683, one fishing in the *Charwell* felt his boat tremble under him, and the lesser fishes seemed affrighted by an unusual skipping. That electricity is the cause sought for, seems deducible from this consideration. Several writers on earthquakes assimilate these vibrations of the earth to those of a musical string: experiments have shewn, that fishes in water may be killed, by the particular tone of a musical string; and 'tis known that electricity will kill animals. They assuredly felt the vibrating motion in the water, which they were absolutely strangers to before. No doubt it made them sick; as those of weak nerves on land. And this circumstance alone precludes any suspicion of subterraneous fires under the ocean. Or, if we were to admit of it, would the boiling of the water exhibit any appearance, like what we are speaking of, either to the water, or to the ship?

Mr. *Flamsteed* likewise concurs in our eighth position^d, “that many people found themselves
“ sick at stomach, and their heads dizzy and
“ light; so that those that had formerly fits of
“ apoplexies, dreaded their return; particularly
“ one gentleman, a surgeon, feeling himself so
“ affected, and fearing a return of his apoplexy,
“ resolved to be let blood, without suspecting the
“ earthquake.”

^d Letter concerning an earthquake.

After the two shocks we felt in *February* and *March* 1749-50. Many people had pains in their joints and back, as after electrifying; many had sickness and head-achs, hyfteric and nervous disorders, and cholicks, for the whole day after, and some much longer, especially people of weak nerves, weak constitutions; some women miscarried upon it; to some it has proved fatal.

To this we must attribute that relation we had of the dog lying asleep before the fire; but upon the earthquake, he suddenly rose up, run about the room, whining and endeavouring to get out.

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 from the point of contact; and likewise somewhat of a sulphureous smell: so that if both flame and smell were discernible in an earthquake; 'tis to be found without going to the bowels of the earth.

Dr. *Hales* mentions that solid bodies are the best conductors of aerial lightening; whence oaks are rent, and iron melted. And in our earthquakes in *London*, the loudest noise was heard near such large stone buildings, as churches with lofty steeples. From the top of these we must apprehend, that the electrical explosion goes off into the open air; as in our experiments, from the points of swords, and the like.

The electrical shock is proportionate to the solid electrified, agreeable to our seventh position.

This

This fully accounts for earthquakes in general, and for many in particular. What can be imagined greater than a shock of the body of the earth? 'Tis greater or less in proportion to the state of electrification. And now we can account for several appearances. In our first earthquake, the lord chancellor, masters in chancery, and several judges, were sitting in *Westminster-Hall*, with their back to the wall of the upper end, which is of a vast thickness. They all relate the severity of the shock, from the wall seeming to push towards them with great violence.

In the earthquake of *September 30, 1750*, Dr. *Stonehouse's* dwelling at *Northampton*, the strongest in the town, was most sensibly shaken. So it was observed likewise, that churches were most subject to its violence. People at divine service felt a great shock, which was like somewhat, as they imagined, that rushed against the church wall and roof.

And thus in the earthquake of 1692, *Deal* castle, whose walls are of immense thickness and strength, shook so sensibly, that the people living in it, expected it was falling on their heads. And this is the case in all earthquakes; the more substantial the building, the more violent the shock is: exactly the mode of electrical vibration.

The city of *Lisbon* is founded on a rock of marble; so much the more susceptible of the electric power, which gave it the vibration. Hence the ruins of churches, palaces, houses, all lie upon their foundations respectively; as the houses of cards made by children, thrown down by a slight shock
of

of a table. And so we are to understand of all the rest in other places.

At the same time, that the force of electricity in solids, is as the quantity of matter ; we see most evidently by innumerable experiments, that water is equally assistant in strengthening and conveying the force of electricity ; and *that* in proportion too to its quantity. And hence is to be deduced the reason of my observation ; that the most frequent and dreadful earthquakes have fallen upon maritime places.

In the dreadful catastrophe at *Port-Royal*, 'tis notorious that its violence was chiefly near the sea. So *Lima* could not suffer without its port of *Callao*. *Lisbon*, and the whole *Atlantic* coast is yet a more tremendous and recent example.

That maritime places are most subject, is a strong argument in favour of electricity ; when both the solid earth, and the quantity of water concur, to make the shock ; exactly as in electrical experiments, when the bottle of water is held in the hand.

Thus, when our mind is discharged of the prejudices of former notions, we discern that every appearance favours the principles we go upon ; That subterraneous explosions, could they pervade, and traverse the earth at pleasure, must at last burst and disperse every thing in their way. Yet 'tis not possible for us to imagine, such a kind of vibrations should follow, either by sea or land, as that we are treating of. But electricity completely answers it. This accounts for that superficial movement of the earth, that universal instantaneous

taneous shock, which made every house in *London* to tremble, none to fall ; that quivering, tremulous, horizontal vibration, highly different from any motion we must conceive to be produced from subterraneous evaporations. Hence authors tell us, *December 30, 1739*, describing an earthquake in the west-riding of *Yorkshire*, it seemed as if the earth moved backward and forward horizontally ; and quivering, with reciprocal vibrations.

From electric vibration only can we account for our tenth position, of springs and fountains being no ways damaged by earthquakes : the motion goes no deeper into the earth, than the force and quantity of the shock reaches ; which generally is not far ; yet it proceeds lower down when the ready passage of a well offers, and *there* affects the water contained in it ; puts it into an intestine vibration, so far as to foul it, and raise mud from the bottom.

It may seem difficult to conceive, how a large portion of the earth's surface should be thus capable of electrification. This difficulty is lessened by reflecting on the nature of electricity, and of the electrical, ethereal fluid, pervading all things : how it is excited by the little motion of a small revolving glass globe. By this we electrify the most solid bodies, to the greatest distance, and with a velocity equal to that of lightning.

We must conceive, that when the electric shock is communicated to one part of the earth, it extends itself proportionably to the force of the shock, and to the quantity of electrified surface ;
and

and to the quality of the matter more or less susceptible of it, more or less apt to propagate it.

Set 1000 men in a row ; let every one communicate with those next him, by an iron wire held in their hands : On an electrical shock they all feel alike, at the same instant ; and this gives a very good idea of the earthquake.

When the earth is broken up in any large degree 'tis by the sea side, where sometimes on a bold shore, whole streets tumble into the sea or into the gaping earth, now falling into the sea, as the key and custom-house at *Lisbon* : sometimes on a flat and sandy shore, whole streets are rolled along the level into the sea.

I am not sensible of any real objection against our hypothesis. As to the eleventh of my positions or circumstances ; it seems true that earthquakes are more frequent in *Italy*, near *Vesuvius*, and by *Ætna* in *Sicily* : And the cause seems apparently owing to those volcanoes, but not so from true reason. This has given the great prejudice to the judgment of the curious, even at this day : But consider the matter impartially, and it will appear so far from being a strong argument in favour of subterraneous eruptions, that it ought to be esteemed a convincing proof of the contrary, and most cogent in favour of my principle. We have but these two or three volcanoes on one quarter of the globe, and two of them toward the warmer climate of it ; whereas earthquakes are innumerable, especially in warmer climes. That there are no volcanoes, no discharges of fire and smoke for a continuance, and abundance, after
earth-

earthquakes ; no suspicions of it either from sight or smell, as we know by innumerable examples, as well as in our own country, and experience ; is demonstration, that this is not the cause. If the volcanoes were the real cause of earthquakes, we ought assuredly to expect, that in the countries thereabouts, the earthquakes ought to be far more extensive than those in other countries, where are no volcanoes ; but this is altogether contrary to experience. For, as the celebrated naturalist *Buffon* observes, such are not extensive, as are near *Ætna* and *Vesuvius*. He further adds, speaking, among many others, of a volcano in the island of *Ternate**, “ that this burning gulph is less agitated “ when the air is calm, and the season mild, than “ in storms and hurricanes : (adding) this con- “ firms what I have said in my foregoing dis- “ course ; and it seems evidently to prove, that “ the fire which makes volcanoes, comes not “ from the bottoms of mountains, but from the “ tops, or at least from a very little depth ; and “ that the hearth (or floor) of the fire is not far “ from the summit of the volcanoes ; for if this “ was not the case, great winds could not contri- “ bute to their conflagration.” And this in general is a corroborative proof of my whole hypothesis. For there can be no great fire in the earth, where there is no great conveyance of air.

We have one volcano in the cold region of *Iceland* ; there is sometimes an earthquake there : but in the countries of that northern latitude, and those of lesser, 'tis obvious in all history, that

* *Histoire Naturelle*. tom. 1. p. 508.

earthquakes are less frequent than in the more southern. Therefore 'tis easy, and very natural to conclude, from all considerations weighed together, that these volcanoes help to put the earth about them, into that vibratory state and condition of electricity, which is the requisite in my hypothesis ; and by that means only, promote a frequency of earthquakes there.

In so surprizing an effect as an earthquake, and so unaccountable a cause as electricity, a cause but recently considered, or known, is it to be wondered at, if some difficulties occur ? can we yet pretend to unriddle all the secrets of electricity, though we know some ; and in my apprehension are sufficiently clear as to the efficient before us ?

Some objections there are, not insuperable. For instance ; in electrical experiments the shock is single, and momentary ; but earthquakes are felt for some few minutes.

To answer which, we need not urge how fear and frights multiply and magnify objects and appearances : but suppose the vibrations last two minutes, there can be no comparison between our little apparatus in experiments, and the stroke upon seven hills, whereon *Lisbon* was built. The vibrations of musical strings are in proportion to their length, and thickness : the same of bells, and the like. There is no comparison between the snap in our little experiments, and a shock upon the globe of the earth ; whence the horrible noise rolling from one eminence to another : as in the air the thunder is re-echoed from one cloud to another.

Again,

Again, some find difficulties from apertures in the earth, and sinkings into the sea, as is the case of the key of *Lisbon*, and the like : So as to mountains opening, and rivers of water gushing out. I profess these instances move me not in the least, to derive them from the bowels of the earth. The electrical stroke from the atmosphere must divide a key, and push it into the sea, or a street that stands on a cliff ; as it divides rocks, cliffs, mountains ; and tumbles them down, as in the case of *Whitestone* cliff *Yorkshire*, in 1755.

Some may object, that if the earth was electrified on an earthquake, every person ought to feel it ; as when touched in the electrical experiments. But we know, the persons in a room where such experiments are tried, are not necessarily electrified. Yet we find in earthquakes, in fact, many affected, as if electrified, with sickness : And all kind of animals are fully sensible of it, and extremely disturbed.

Sometimes the case of *Herculaneum*, and such fancied accidents are quoted, as places sunk by force of an earthquake. But this is an erroneous position. The city remains entire. It was not shaken in its last catastrophe, but buried in *lava* poured upon it from mount *Vesuvius*. These, and such like, are little objections, which it is not worth while to be elaborate in answering ; as having no foundation on principles of philosophy.

May 1, 1753, I received a letter from *Peterborough*, by order of the literary society there, with an account of a woman at *Sutton* by *Wansford*,

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who

who had been quite deaf for two years last past, but was perfectly restored to her hearing on *Sunday September 30* preceding, being the day of the earthquake there. She found herself restored half an hour before the shock.

April 1751, we had an account from *Edinburgh* of a person restored to the use of speech, from a resolution of the nerves, by electrifying. His name *Robert Mowbray*. These and many like cases confirm our reasoning.

Though the power that produces these amazing struggles in the elements, be manifestly one, and the same ; yet it admits of some difference in its action ; not only as it may be more or less forcible, of more or less extent, or as to the different object of its action, but likewise in its manner. And this points out some names of distinction, which are at least useful, in all parts of learning and philosophy.

1. We may therefore denominate one of these appearances, the *air-quake*. This shews itself only in the air, in a most horrible rumbling noise, like many cannon let off, echoing from one hill to another. It may be called terrestrial thunder. The earth feels not its force, or but slightly, or partially, here and there ; must not be in a proper electric state, and therefore not fully susceptible of the shock. This is owing to a preceding rainy, moist season : which is always adverse to electricity.

A loud clap of thunder in the atmosphere, may be heard over a circle of 500 miles diameter.

The

The same clap discharged at the surface of the earth the 1st of *August* last (1755) was heard all over the counties of *Lincoln* and *Rutland*, and part of all the circumjacent counties. It arose to an earthquake, wherever the ground was in a proper disposition for it more or less. They that can suppose this phenomenon to arise from under-ground, are not to be argued with.

2. A second kind we may call a *water-quake*; which exerts itself in the air and water, as this on *November 1*, with us; causing a most vehement agitation of that element, lifting it up, and throwing it down by pulses, tossing it over the banks of canals, whirling about ships and boats, shaking, and dashing them one against another, stirring up the water from the very bottom, raising it from the bottom of wells, and the like.

This appearance occurs in the middle of the ocean: on the land here and there, accompanied with real shocks of an earthquake, wherever the earth is in an electric state. This phenomenon must acknowledge the same aerial origin.

The water is a ready object of its force, both from its mobility, and from its solidity. It chuses to run up rivers, to any length; to run along the shores, as ready conductors, according to our last position. They that can fancy subterraneous boilings, like a culinary fire, under all the canals, lakes, rivers, sea-shores, and the ocean, affected at the same time, over a quarter of the globe, especially

in the vessels of water prepared for brewing, are not to be argued with.

We are to conceive, that the electric power falls furiously upon water, by reason of the extreme solidity of the component particles of that most wonderful fluid element : whose sole property it is, of all matter, to be absolutely incompressible. Hence it more readily attracts, and assists the vehemence of the elemental, electric fire. Hence it so readily falls on rocks, mountains, steel, solid buildings, metals, the bones, and joints of animals, and whatever is of the most specific gravity.

This therefore causes a thump at the bottom of a ship at sea, as if striking on the ground; this shakes, and quivers the masts, like an aspen leaf.

3. The third diversity we call properly the *earthquakes* : a tremor of the surface of the earth, accompanied with the two preceding, especially the first, the rumbling noise. These undulations are boundless, as to space, time, or violence, as far as the earth is prepared to receive them. For if a musical string be not rightly stretched, it has no tone. So a wire, in electrical experiments, never so far extended, receives the touch, through its whole length.

It cannot be hard to observe, that all considerations shew the impossibility of a fire underground, perpetrating these dire calamities of earthquakes. The like as to the agitation in the waters, which was perceived even in great vessels

of water for brewing : and more, even in lead when in fusion, at that same instant of time, as I was credibly informed.

We must likewise affirm, that the fire and smoak of volcano's, is the effect of the electric stroke, not the cause. The great noise is pre-lusive of the fire, that kindles their component sulphurs, at the very summit ; like a match of brimstone struck by a flint and steel. Nor can there be any fire, low in the earth, where there is no conveyance of air, no more than in an exhausted receiver. And though fires are found in the bottom of coal-mines, and the like, where the air can descend ; yet we never hear of earthquakes caused by them.

4. A fourth kind, I hold to be what we vulgarly call a *water-spout*, which is seen both on the water, and on the land. 'Tis a partial exercise of the aerial power, that lifts up the water in the ocean, rivers, wells, canals. A single vortex or column, sometimes visible, of a great height.

In the accounts from *Cadiz* and other places, the water is seen coming from the great ocean, like a mountain, and when at the shore, covering the land : and many of these like columns or ridges 50 or 60 foot high, more or less, succeeding one another. The like appearance, *cæteris paribus*, in lakes, canals. All these are owing to the same aerial power that makes the water-spouts.

These four kinds proceed all from the same cause, under some different circumstances, single or complex, greater or lesser. The *rationale* of them we leave to further disquisition, content to point out some of them, and enumerate their species.

We have seen universally that earthquakes and agitations happen in a serene sky. We have asserted their cause to be electrical strokes from the atmosphere, the same as thunder and lightning. Now that thunder and lightning which produces earthquakes, is found in a clear sky, free from clouds, was known to that great genius *Horace*, as appears very fairly from Ode XXXIV. of his first book ; but not commonly understood, from want of a true pointing. Thus,

—*Namque Diespiter*

Igni corusco nubila dividens

Plerumque ; per purum, tonantes

Egit equos, volerremque currum,

Quo bruta tellus, et vaga flumina,

Quo Styx et invisi horrida Tænari

Sedes, Atlanteusque finis

Concutitur.

A comma is usually put after the word *dividens*, but erroneously. Mr. *Baxter* discerned it ought to be after the word *plerumque*, otherwise 'tis not agreeable to that good sense we ought to find in our poet : and it now shews that he was a philosopher too.

It

It may be thus translated, and accommodated to the present times.

—For hitherto great *Jove*,
 Who o'er the clouds his thundring chariot drove :
 Of late his fiercest lightning has been seen
 To dart impetuous thro' the sky serene.
 The solid earth an awful tremor feels,
 The rivers dance before his chariot wheels :
 To *Afric's* shores the rapid shock extends,
 E'en to the dreadful *Stygian* cave descends ;
 The yawning realm of *Tænarus* appears,
 Awakens conscience with unusual fears.





PHAEOMENA

OF THE

Great EARTHQUAKE

Of *November 1, 1755*, in various parts of the
Globe.

EUROPE.

In GREAT-BRITAIN and IRELAND.

BARDFIELD, *Essex*. The waters in ponds greatly agitated between 11 and 12 in the morning.

BARLBOROUGH, *Derbyshire*. Between 11 and 12, in a boat house on the west side of a large body of water, called *Pibley Dam*, suppos'd to cover at least thirty acres of land, was heard a surprizing and terrible noise, and a large swell of water came in a current from the south, and rose two feet on the sloped dam head at the north end of the water. It then subsided, but returned again immediately, though with less violence. The water

ter continued thus agitated for three quarters of an hour, but the current grew weaker and weaker, till at last it entirely ceased. During this disturbance, not a breeze of wind was heard, nor a wave seen upon the surface. A hardy young fellow was sent to the boat-house to see if any beast was there plunged in the water, but was so shock'd with the noise, and by the boats tumbling about and beating against the sides of the house, that when he returned he was not able, at first, to give a rational answer to any question that was asked him. When all was still and quiet, it appeared by a stake which had been drove down in the pond when the boat-house was built, that the water on that spot had risen about eight inches.

BOCKING, *Essex*. The same as at *Bardfield*.

BUSBRIDGE, *Surrey*. (near *Godalmin*) At half an hour after ten in the morning, the weather being remarkably still, without the least wind, in a canal near 700 feet long, and 58 feet broad, with a small spring constantly running through it, a very unusual noise was heard at the east end, and the water there was observed to be in great agitation; it raising it self in a heap or ridge in the middle, which extended length-wise about 30 yards, and between two and three feet above the usual level: After which the ridge heeled or vibrated towards the north side of the canal, with great force, and flowed above eight feet over the grass walk on that side. On its return back into the canal, it again ridged in the middle, and then heeled, with yet greater force, to the south side, and flowed over its grass walk; during which latter

latter motion, the bottom on the north side was left bare of water for several feet wide. The water being returned a second time into the canal, the heelings grew less and less, yet so strong as to make it flow several times more over the south bank, which is something lower than the other. In about a quarter of an hour after the first appearance, the water became quiet and smooth as before. During the whole time there was a great perturbation of the sand from the bottom, with a noise like to that of water turning a mill. The highest part of the walk, over which the water flowed, was about 20 inches above the water level. No motion was taken notice of in the water at the west end of the canal.

CAVERSHAM, *Oxfordshire*. (near *Reading*) People were alarmed with a very great noise about 11 in the morning, as if part of their house had been falling down: Upon examination however it did not appear, that the house was at all damaged; but a vine which grew against it was broken off, and two dwarf trees were split.

COBHAM, *Surrey*. Between 10 and 11, a person was watering a horse in hand, at a pond fed by springs, which had no current. Whilst the horse was drinking, the water ran away from him, and moved towards the south with swiftness, and in such a quantity, as left the bottom of the pond bare; then returned with that impetuosity, which made the man leap backwards, to secure himself from its sudden approach. It went back again to the south, with a great swell, and returned again. Its rise was above a foot. The ducks were

were alarmed at the first agitation, and flew all instantly out of the pond. There was a particular calm all this time.

CONISTONE-WATER, *Cumberland*. (a lake about five miles in length) A ferry man standing at their landing place, as he guesses about 10 in the morning, was surprized to see the water flow above a yard upon the bank when there was not the least wind, and the water quite calm; and continued its motion backwards and forwards about five minutes. The perpendicular rise might be about a foot.

CRANBROOK, *Kent*. The people were very much alarmed and fancied they felt an earthquake. The waters of several ponds, in this and the adjacent parishes, were in such motion, that they overflowed their banks, and then returned back, and overflowed the other side.

CORK, *Ireland*. At 36 minutes after 9 two shocks of an earthquake were felt at about half a minute's interval: The limits of the places affected were, southward, *Watergate-lane*, *Christchurch-lane*, and *Playhouse-street*; northward, *Broad-lane*, *Coal-Quay*, and *Draw-bridge*.

CRESTON-FERRY, *Devon*. (a mile south-east of *Plymouth*) About 4 in the afternoon, almost immediately after high-water, the tide made a very extraordinary out, or recess, and left two laden passage-boats, at once, quite dry in the mud, though they were, a minute or two before, in four or five feet water. In less than eight minutes the tide returned with the utmost rapidity, and floated both the boats again, so that they had
fix

six feet water. The sea sunk and swelled, tho' in a much less degree, for near half an hour longer, and at the next morning's tide there, several very large surges, which drove ships from their moorings, broke some of the hawsers, and twirled vessels about in a very odd manner.

CRUNILL-PASSAGE, *Devon*. Over an arm of the sea, about two miles west of *Plymouth*, the same phænomena were observed, as at *Creston-Ferry*.

DUNSTALL, *Suffolk*. (near *Bury*) The water of a pond rose gradually, for several minutes, in the form of a pyramid, and fell down like a water-spout; whereas other ponds thereabouts had a smooth flux and reflux, from one end to the other.

DURHAM city. (near it) About half an hour after 10, a gardener was alarmed by a sudden rushing noise from a pond; as if the head of the pond had broken down: when casting his eye on the water, he saw it gradually rise up, without any fluctuating motion, till it reached a grate, which stood some inches higher than the common water-level, thro' which it discharged itself for a few seconds. Then it subsided as much below the mark it rose from, as it was above it in the greatest elevation, and continued thus rising and falling about six or seven minutes, making four or five returns in about one. The water still continued to have some commotion, but it was nothing considerable. The ebb and flow were each about half a foot in the perpendicular. The pond is about 40 yards long, and 10 broad.

EARLY-COURT, *Berks*. (near *Reading*) About 11 o'clock, a gardener standing by a fish-pond, felt

felt a most violent trembling of the earth, which lasted upwards of fifty seconds: Immediately after which, he observed a motion of the water, from the south end of the pond to the north end, leaving the bottom on the south end altogether without water, for the space of six feet. It then returned, and flowed at the south end, so as to rise three feet up to the slope bank, and immediately went back again to the north, where it likewise flowed three feet up the bank: And in the time between the flux and reflux, the water swelled up in the middle of the pond, collected in a ridge, about 20 inches higher than the level on each side, and boiled like a pot. This agitation from south to north, and from north to south alternately, lasted about four minutes; and there seemed to be little or no motion in the direction of east and west, the weather being perfectly calm during the whole time.

EASTHWAITE-WATER, *Cumberland*. (a lake about a mile and a half in length, near *Hawkeshead*) A like agitation, though in a less degree, and shorter continuance, as at *Conistone-water*, and at the same time.

EATON-BRIDGE, *Kent*. In a pond, about an acre in size, a dead calm, and no wind stirring, some persons heard a noise, and imagining something had tumbled in, ran to see what was the matter; when, to their surprize, they saw the water, open in the middle, so that they could see a post a good way down, almost to the bottom, and the water dashing up over a bank about two foot

foot high, and perpendicular to the pond. This it did several times, making a great noise.

ENFIELD, *Middlesex*. Agitations on the water.

EYAM-EDGE, *Derbyshire*. (in the Peak) The overseer of the lead mines, sitting in his writing room, felt, about 11 o'clock, one shock, which very sensibly raised him up in his chair, and caused several pieces of lime or plaister to drop from the sides of the room. The roof of it was so violently shook, that he imagined nothing less than the engine shaft was run in; whereupon he immediately went to see, and found the shaft open, and all things about the spot in their proper order. In the morning, coming through a field about 300 yards from the mines, there was nothing uncommon to be seen, but in his return at evening he observed a cleft about one foot deep and six inches over; its continuation from one end to the other, was near 150 yards, being parallel to the range of the vein on the north side. These were the most remarkable circumstances which happened on the surface of the earth.

Two miners at the aforesaid time were employed carting, or drawing along the drifts, the ore and other minerals to be raised up the shafts. The drift, in which they were working, is about 120 yards deep, and the space from one end to the other 50 yards, or upwards. He at the end of the drift had just loaded his cart, and was drawing it along, but was suddenly surprized by a shock, which so terrified him, that he immediately quitted his employment, and ran to the west end of the drift to his partner, who was not less

less terrified than himself. They durst not attempt to climb the shaft, lest that should be running in upon them, but consulted what means to take for their safety. Mean while they were alarmed by a shock much more violent than the former; which put them in such a consternation, that they both ran precipitately to the other end of the drift. There was another miner working at the east end of the vein, about 12 yards below their level, who called out to them, imagining they were in danger of being killed by the shafts running in upon them, which he supposed was the case; and told them, if by any means they could get down the shaft to him, they would be more secure, because the cavity, where he was working, was encompassed with solid rock. They went down to him, where after observing they had neither of them received any misfortune, he told them that the violence of the second shock had been so great, that it caused the rocks to grind one upon another. His account was interrupted by a third shock, which, after an interval of four or five minutes, was succeeded by a fourth; and about the same space of time after, by a fifth; none of which were so violent as the second. They heard after every shock a loud rumbling in the bowels of the earth, which continued about half a minute, gradually decreasing, or seeming at a greater distance. They imagined, that the whole space of time, from the first shock to the last, might be about 20 minutes; and they tarried about ten minutes in the mine, after the last shock. As they went along the drifts, they observed, that several
pieces

pieces of minerals were dropped from the sides and roof, but all the shafts remained entire, without the least discomposure: The space of ground at the aforesaid mines, wherein it was felt, was 960 yards, which was all that was at that time in workmanship.

FINCHINGFIELD, *Essex*. Between 11 and 12 the water of a pond, which has no communication with any river, ran up hill into a ditch. Just before the agitation of the water, the geese in the pond screamed vehemently.

FRAMLINGHAM, *Suffolk*. (near *Ipswich*) A large pond was greatly agitated.

GAINSBOROUGH, *Lincolnshire*. The water in this port rose five or six feet, and fell again in a minute or two.

GUAVA'S-LAKE, *Cornwal*. A ketch of war veered round upon her anchors, keeping her head by turns to the flux and reflux; and in the decline of the commotion they hove the log to estimate the velocity of the water, and found it to run at the rate of seven miles in an hour.

GUILFORD, *Surry*. (near it) In a mill-pond, a great swell and agitation of the water was observed by a person who stood over it all the while, on a bridge; and in a back stream it was very considerable, and came with violence against the bank, but no sensible reflux was observed.

HEYLE, *Cornwal*. (a little harbour about four miles north of the *Mount*, on the *Severn* sea) The agitation did not make its appearance, till an hour or little more after the ebb began, or about 4 in the afternoon, which is easily accounted for
(says

(says the observer) by the circuit of land at the extremity of the county, which the swell must have made before it could reach into the north chanel to *St. Ives* and *Heyle*. In this inland half-tide harbour it continued visible but an hour and half; the greatest flux was about the middle of that time, the surge being then seven feet high; but in general it rose and fell but two feet only; owing, as he supposes, to the force and quantity of water being broke in its advances into so retired a creek.

HORSMANDEN, Kent. The same phænomena as at *Cranbrook*.

HULL, Yorkshire. The same as at *Gainsborough*.

HUNSTON, Norfolk. Two gentlemen went out a shooting on the sea-shore, and were in great danger of being drowned by the sea's sudden flowing before its usual time.

St. Ives, Cornwall. (at the peer) The water rose between eight and nine feet, and floated two vessels, before quite dry, but all smooth; no sea broke.

KINSALE, Ireland. Between the hours of two and three in the afternoon, the weather being very calm, and the tide near full, a large body of water suddenly poured into the harbour, with such rapidity, that it broke the cables of two sloops, each moor'd with two anchors, and of several boats lying between *Scilly* and the town; which were carried up, then down the harbour, with a velocity far exceeding that of a ship or boat, though favoured with all the advantageous cir-

cumstances of tide and wind, in any degree of violence : But just at the time that universal mischief was thought unavoidable by all the vessels running foul of one another, an eddy whirled them round several times, and hurried them back again with the same rapidity. This was several times repeated ; and while the current rushed up at one side of the harbour, it poured down with equal violence at the other. A vessel that lay all this time in the pool, did not seem to be any ways affected ; nor was the violence of the currents much perceived in the deeper parts of the harbour, but raged with most violence on the flats. The bottom of the harbour, which is all a slab, was much altered, the mud being washed from some places, and deposited in others. The perpendicular rise of the water at one quay was measured five feet and a half, and is said to have been much higher at the market quay, which it overflowed and powered into the market-place with such rapidity, that some who were on the quay, immediately ran off, on the first rise of the water, but could not do it with expedition enough to prevent their being overtaken, and up to the knees. The agitations of the water were communicated some miles up the river, but, as in the harbour, were most perceivable in the shallowest places. The successive risings and fallings of the water seemed to continue about ten minutes, and then the tide returned to its natural course. Between 6 and 7 in the evening the water rose again, though not with so great violence as before ; and it continued alternate ebbs and flows till 3 in the morning. The
waters

waters did not rise gradually at first, but with a hollow and horrid noise rushed in like a deluge, rose six or seven feet in a minute, and as suddenly subsided : It was as thick as puddle, very black, and stank intolerably. By different accounts the water was affected in the same manner, all along the coast, to the westward of this harbour.

LANDS-END, *Cornwal*. The commotion of the waters was perceived there.

LEE, *Surrey*. (in *Whitley* parish) A canal or pond was so violently agitated, that the gardener, on the first appearance, ran for help, thinking a number of otters were under the water destroying the fish.

LOCH-KETERIN, *Scotland*. Agitated at the same time as *Loch-Lommond*, which see.

LOCH-LOMMOND, *Scotland*. At half an hour past nine in the morning, all of a sudden, and without the least gust of wind, the water rose against its banks with great rapidity, but immediately retired, and in five minutes time subsided, till it was as low in appearance, as any body then present had ever seen it in the greatest summer drought ; and then it instantly returned towards the shore, and in five minutes time rose again as high as it was before. The agitation continued at this rate till fifteen minutes after ten the same morning, taking five minutes to rise, and as many to subside ; and from fifteen minutes after ten, till eleven, every rise came somewhat short in height of that immediately preceding, taking five minutes to flow, and five to ebb, untill the water was settled, as it was before the agitation. The height to which

the loch rose perpendicular, was measured and found to be two feet, four inches.

LOCH-LONG, *Scotland*. Agitated at the same time as *Loch-Lommond*, which see.

LOCH-NESS, *Scotland*. At half an hour after nine, a very great agitation of the waters was seen by divers persons; and about ten the river *Oich*, which lies on the north side of fort *Augustus*, and runs from west, into the head of the loch, was observed to swell very much, and run upwards, from the loch, with a pretty high wave, about two or three feet higher than the ordinary surface, with a pretty quick motion against the wind, and a rapid stream, about two hundred yards up the river; then broke on a shallow, and flowed about three or four feet on the banks, on the north side of the river, and returned again gently to the loch. It continued ebbing and flowing in that manner for about an hour, without any waves so remarkable as the first, till about eleven o'clock, when a wave higher than any of the rest came up the river, and, to the great surprize of all the spectators, broke with so much force on the low ground, on the north side of the river, as to run upon the grass upwards of thirty feet from the river's bank. *Loch-ness* is about twenty miles in length, and from one to one and a half mile broad; bears from south-west to north-east. It is vastly deep, its soundings in many places being from one hundred, to an hundred and thirty-five fathom, which is greatly below the level of the sea at *Inverness*. Its sides are most part rocky, and it deepens immediately from them. About three
musket-

musket-shot from the river *Oick* it measures about one hundred and twenty fathom in depth. There was no extraordinary muddiness observed in the water, upon this occasion, though it did not appear quite so clear as usual. The morning was cold and gloomy, and a pretty brisk gale of wind blowed from west-south-west.

LUTON, *Bedfordshire*. The water of a pond was strongly agitated, and several times overflowed its banks on one side, and ebbed six feet on the other; this was between ten and eleven in the morning.

MEDHURST, *Suffex*. In a mill-pond, the swell of the water, rolling towards the mill, was so remarkable, that the miller imagined a sluice had been opened at the upper end of the pond, and had let a back water into it; but upon search it was found shut as usual: Upon its retreat, it left some fishes upon dry land. Below the mill the swell of the water was so great, as to drive the stream upwards, back into the conduit of the mill. The pond in lord *Montacute's* park, in the neighbourhood, was likewise greatly agitated at the same time.

MOUNTS-BAY, *Cornwal*. A little after two in the afternoon, the weather fair and calm, as it had been for six days before, the barometer unusually high, the thermometer about temperate, and the little wind there was, at north-east, there happened here, and the parts adjacent, the most uncommon and violent agitation of the sea ever remembered. About half an hour after ebb, the sea was observed at the *Mount-pier* to advance

suddenly from the eastward. It continued to swell and rise for the space of ten minutes; when it began to retire, running to the west, and south-west, with a rapidity equal to that of a mill-stream descending to an undershot wheel: It ran so for ten minutes, till the water was six feet lower, than when it began to retire. The sea then began to return, and in ten minutes it was at the before-mentioned extraordinary height: In ten minutes more it was sunk as before, and so it continued alternately to rise and fall between five and six feet, in the same space of time. The first and second fluxes and refluxes were not so violent at the *Mount-pier* as the third and fourth, when the sea was rapid beyond expression, and the alterations continued in their full fury for two hours: They then grew fainter gradually, and the whole commotion ceased about low water, five hours and a half after it began. At the mount the fishermen got to their boats, then riding off the pier, as soon as the commotion was observed, concluding that a violent storm was at hand: They were no sooner on board, than their boats were heaved in with the surf; but they were no sooner in the pier, and struggling to secure themselves and boats, as much as their astonishment would permit, than their boats were hurried back again, through the gap or mouth of the pier, with incredible velocity: When they had gone off as far as the reflux determined, they were carried in, and out again, with an impetuosity, which no ropes could withstand, and which would have destroyed both men and boats immediately, if in
their

their passage, they had touched the least stone of the pier. What preserved them, was not the rudder, or the oar, but the same stream and current, which put them in danger; for it had neither in or out let but through that narrow gap, and therefore set in directly, and out.

MOUSHOLE-PIER, *Cornwal.* (in *Mounts-bay*) The agitations of the sea did not materially differ from those at *Newlin-pier*.

NETTLEBED, *Oxfordshire.* A reservoir there called *Wombone-pond*, was found quite empty of water, the bottom having sunk within the earth and left an unfathomable cavity. It had been observed to be full at eight o'clock the night before.

NEWLIN-PIER, *Cornwal.* (a mile west of *Penzance*) The flux was observed to come in from the southward, the eastern current (says the curious observer) being quite spent. It was nearly at the same time as at *Mounts-bay* and *Penzance*, but in a manner somewhat different; it coming on like a surge or high crested wave. The first agitations were as violent as any; and after a few advances and retreats, at their greatest violence, in the same space of time as at the *Mount*, the sea grew gradually quiet, after it had rose, to the infinite amazement of the spectators, ten feet perpendicular at least: This is five feet more than at the *Mount-pier*, and two feet more than at *Penzance*, attributed, by the observer, to the angle or creek in which *Newlin* lies; wherein the waters were resisted, and accumulated by the straitness of the shores, and the bent of the western land; whereas at *Penzance* the waters were less confined,

and consequently could not rise so high; but at the *Mount* (at that time an island) the sea had full room to spread, and disperse it self, and there rose least of all. See *Penzance*.

OICH, river, *Scotland*, greatly agitated. See *Loch-Nefs*.

PEERLESS-POOL, *Middlesex*. (in *Old-street* parish, near *London*) Between the hours of ten and eleven in the morning, one of the waiters there being engaged with his fellow-servant, in some business, near the wall inclosing the ground which contains the fish-pond, and accidentally casting his eye on the water, was surprized to see it greatly moved, without the least apparent cause, as the air was entirely calm; he called to his companion, who was equally struck with the sight of it. Large waves rolled to and from the bank near them, at the east end, for some time, and at last left the pond dry for several feet, and in their reflux overflowed the bank ten or twelve feet, as they did the opposite one, which was evident from the wetness of the ground about it. This motion having continued five or six minutes, the two waiters stept to the cold bath near the fish pond, but no motion was by them observed in it, nor by a gentleman who had been in it, and was then dressing, and who went immediately with the waiters to the fish-pond, and was a third witness of the agitation there. When all had ceased, these three went to the pleasure bath, between which and the fish-pond the cold bath is situated; they found it then motionless, but to have been agitated in the same manner with the fish-pond, the water leaving

plain marks of its having overflowed the banks, and risen to the bushes on the sides of them.

PENZANCE, *Cornwal*. The pier lies three miles west of the *Mount*, and the reflux was first observed here forty-five minutes after two: The influx came on from the south-east, and south south-east: From whence the observer gathers, that the force, from which the agitation proceeded, lay at south nearly, or south-west of the bay, and the sea reaching first the eastern lands (which project a great deal more than those of the west) was thence reflected, and came upon the *Mount* in an easterly direction: but further on the west this eastern current had lost its strength, and the sea came into *Penzance* from the south-south-east, more directly from the points of its momentum. Here the greatest rise was eight feet, and the greatest violence of the agitation about three o'clock. See *Mounts-bay*.

PLYMOUTH, *Devonshire*. About four in the afternoon, there was an extraordinary *boar*, as the sailors call it. The sea seemed disturbed about twenty minutes before, though there was very little wind that day, or for some days before. The sky seemed that day very cloudy, in the morning very full of little fiery red clouds, in the afternoon very louring, and in many places of a very odd copper-colour; the atmosphere excessively thick and dark, but not a drop of rain fell. The boar drove several ships from their moorings, and broke some of the hawfers.

PONTY-POOL, *Monmouthshire*. (near it) The river *Frood* sunk, by the fall of a rock, into the earth, and is lost; not yet having been discovered
to

to have broken out any where again, though it may be observed to run about ten yards underground.

POOL, *Dorsetshire*. Between ten and eleven o'clock in the morning, the sea at the quay was violently agitated, though calm just before: Ships were tossed and broke from their moorings. Some felt a slight earthquake at land.

PORTSMOUTH, *Hants*. About thirty-five minutes after ten in the morning there was observed, in the dock-yard, an extraordinary motion of the waters in the north dock, and in the bason, and at two of the jetty heads. In the north dock whose length is two hundred and twenty-nine feet, breadth seventy-four feet, and at that time seventeen feet and a half depth of water, the *Gosport* man of war of forty guns, was just let in to be dock'd, and well stay'd with guys and hawsers. On a sudden, the ship ran backward near three feet; and, by the libration of the water, the gates alternately opened and shut, receding from one another near four inches. In the bason, whose length is about two hundred and forty feet, breadth two hundred and twenty feet, and at that time about seventeen feet depth of water, shut in by two pair of gates, lay the *Berwick* of seventy guns, the *Dover* of forty guns, both in a direction nearly parallel to the *Gosport*, and a merchant ship of about six hundred tons, unloading of tar, lying in an oblique direction to the others. These ships were observed to be agitated in like manner with the *Gosport*, and the tar ship to roll from side to side. The swell of the waters against the sides of
the

the basin was observed to be nine inches ; one of the work-men measured it between the librations. The *Nassau*, a seventy gun ship, lying a long-side a jetty head, between the north dock and the basin ; also the *Duke*, a ninety gun ship, lying against the next jetty head, to the southward, both in a direction nearly at right angles to the others, were observed to be rocked in the same manner, but not quite so violently. The dock and basin lie nearly east and west, on the west side of the harbour.

ROCHFORD, *Essex*. About ten in the morning, in a pond adjoining to the church-yard, the water was observed to flow a considerable way up the mouth of the pond, and then returning, to flow up the opposite side, repeating this sort of motion for about three quarters of an hour. At the very time of this fluctuation, two other ponds, which are but a small distance from the former, were remarked to be still and quiet. The motion of the water in the first pond was only from east to west, and from west to east, alternately. This pond is very large, and almost round : Its mouth is on the east side. The two neighbouring ponds lie in length from north to south, and are comparatively very narrow in their breadth from east to west.

SHIRBURN-CASTLE, *Oxfordshire*. At a little after ten in the morning, a very strange motion was perceived in the water of a moat which encompasses the house. There was a pretty thick fog, not a breath of air, and the surface of the water all over the moat as smooth as a looking-glass,

glass, except at one corner, where it flowed into the shore, and retired again successively, in a surprising manner. How long it had done so before, or in what manner it began to move, is uncertain; the flux and reflux, when seen, were quite regular. Every flood began gently; its velocity increased by degrees, till at last, with great impetuosity, it rushed in till it had reached its full height, at which it remained for a little while, and then again retired, at first gently ebbing, at last sinking away with such quickness, that it left a considerable quantity of water entangled amongst the pebbles, laid to defend the bank, which ran thence in little streams over the shore, now deserted by the water, which at other times always covers it. As the slope of the sides of the moat is very gentle, the space left by the water at its reflux was considerable, though the difference between the highest flood and lowest ebb of these little tides, if the expression may be allowed, was but about four inches and an half perpendicular height; the whole body of water seeming to be violently thrown against the bank, and then retiring again, while the surface of the whole moat, all the time, continued quite smooth, without even the least wrinkle of a wave. The time it took up in one flux and reflux, as it was not then observed, cannot be guessed at. Several pieces of white paper lay at the bottom of the water, about four foot deep: These could be perceived to move backward and forwards, keeping pace with some weeds, and other things, which floated on the top of the water, as it ebb'd
and

and flow'd. Lord viscount *Parker*, who had observed these reciprocations, being desirous to know, whether the motion was universal over the moat, sent a person to the other corner of it, at the same end that himself stood, and about twenty-five yards from him, to examine whether the water moved there, or not. He could perceive no motion there, or hardly any: But another, who went to the north-east corner of the moat, diagonally opposite to his lordship, found it as considerable as where he was. His lordship imagining, that in all probability the water at the corner diagonally opposite to where he was, would sink, as that by him rose, he ordered the person to signify, by calling out, when the water by him began to sink, and when to rise. This he did, but to his lordship's great surprize, he found, that, immediately after the water began to rise at his own end, he heard his voice calling that it began to rise with him; and in the same manner heard that it was sinking at his end, soon after he perceived it to sink by himself. They might be about ninety or an hundred yards asunder. His lordship sent a person to a pond just below where himself stood, who called to him in the same manner. The water rose and fell in that pond; but though he stood at the south-west corner of that pond, as my lord did at the south-west corner of the moat, it did not rise and fall by him in that pond, at the same time as it rose and fell by his lordship in the moat, but sunk sometimes when the moat rose, and rose when the moat sunk, as it seemed by his calling, the rising and falling seeming to be quicker than in the moat, though but little: He might stand
about

about forty yards off. His lordship sent to three other ponds, in all which the agitation was very considerable. The swells which succeeded one another, were not equal, nor did they increase or diminish gradually; for sometimes, after a very great swell, the next two or three would be small, and then again would come a very large one, followed by one or two more as large, and then less again. His lordship having stood by the moat a good while, went away, and returning again in about half an hour's time, found it perfectly still.

STONEHOUSE LAKE, *Devonshire*. (communicating with an arm of the sea) The boar or swell came in with such impetuosity, that it drove every thing before it, tearing up the mud, sand and banks, and broke a large cable, by which the foot passage boat is drawn from side to side of the lake.

SWANZEY, *Glamorganshire*. (in *Bristol* channel) See *White-rock*.

TARFF river, *Scotland*. (south of fort *Augustus*) Was agitated at the same time and manner as the river *Oich*. See *Lockness* and *Oich*.

TENTERDEN, *Kent*. Between 10 and 11 in the morning, several ponds here and in the neighbourhood were greatly agitated; the water being forced up the banks, with much violence, foaming, fretting, and roaring like the coming in of the tide. Some flowed up three times in this manner, others circled round in eddies, absorbing leaves, sticks, &c.

THAMES, river. (at *Rotherithe*) Some persons being in a barge, unloading timber, between 11 and 12 o'clock, were surprized by a sudden heaving up of the barge, from a swell of the water,

not

not unlike what happens when a ship is launched from any of the builders yards in the neighbourhood. But the state of the tide did not then suit with the launching of ships, and they were afterwards certain that no ship was launched at that time.

TOPSFIELD, *Essex*. The water of a pond rose very high.

TUNBRIDGE town, *Kent*. The waters agitated.

WHITEHAVEN, *Cumberland*. The waters agitated.

WHITE-ROCK, *Glamorganshire*. (above a mile above *Swansey*) About two hours ebb of the tide, and near three quarters after six in the evening, a great head of water rushed up with a great noise, floated two large vessels, the least of them above two hundred tons, (one whereof was almost dry before) broke their moorings, and hove them across the river, and had like to overset them, by throwing them on the banks. The whole did not last ten minutes, the rise and fall, and what is most remarkable, it was not felt in any other part of the river, so that it should seem to have gushed out of the earth at that place: For near *Swansey* town, and mouth of the river, there is a passage-boat, that was passing at that time, and had been for the whole day, and there nothing was felt of it.

WINDERMERE-WATER, *Cumberland*. (a lake about ten miles long from north to south) About ten o'clock in the forenoon, a fishing-boat being drawn aground, one of the men ashore, and the other sitting in the boat, the lake quite full, and as smooth as glass, and not a breath of wind; on a sudden the water swelled, floated the boat, heaved it up about its length farther upon land, and took it back again, in the falling back of the wave.

This flux and reflux continued about eight or ten minutes, gradually decreasing : Here they heard no remarkable noise. Some ferry-men, busy at the same time on shore, about the middle part, gave the like account in every particular, only that their boat was moored, and could not be driven on shore ; the swell they judged to be about knee-high above the common surface. Some husbandmen that were at work that forenoon in a field, within sight of the lake, about two miles and a half from the foot or south end of it ; about ten, heard a noise from towards the water, like, as they imagined, the sound of the slate off the whole side of any large building, sliding down the roof at once, and expected it to be some strong gust of wind coming at a distance : The water was quite still before and smooth, but on that noise they observed a narrow rippling in the lake, from the point of a rock.

WYMANSDEL-MEARE, *Westmoreland*. Was agitated in a very extraordinary manner ; for in an instant the waters rose seven feet, and again as soon subsided ; so that two fisher-men who were in a boat, near the edge of the lake, found themselves by one wave carried into it a considerable way, and were so astonished with the sudden transportation, as to declare they imagined that the last day was come.

YARMOUTH, *Norfolk*. A little before noon, without any wind stirring, the water in the haven was violently agitated, and suddenly rose six feet, and the ships had an uncommon motion, so that the caulkers left off work for some time.

IN BOHEMIA.

TOPLITZ (a village famous for its medicinal baths, nine *Bohemian* miles north-west of *Prague*) These waters were discovered in the year 762; from which time the principal spring of them had constantly thrown out the hot water in the same quantity, and of the same quality. On *November 1, 1755*, between eleven and twelve in the morning, the chief spring cast forth such a quantity of water, that in the space of half an hour all the baths ran over. About half an hour before this vast increase of the water, the spring grew turbid, and flowed muddy; and having stopped intirely near a minute, broke forth again with prodigious violence, driving before it a considerable quantity of a reddish oker, or *crocus martialis*: After which it became clear, and flowed as pure as before; and continues still to do so; but it supplies more water than usual, and that hotter, and more impregnated with its medicinal quality.

IN FRANCE.

ANGOULESME, capital of *Angoumois*; about a league from this city a subterraneous noise, like thunder, was heard, and presently after the earth opened and discharged a torrent of water mixed with red sand. Most of the springs in the neighbourhood sunk, in such a

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manner,

manner, that for some time it was thought they were quite dry, and the *Charante* at the same time sunk considerably, and then swelled up in a surprising manner.

BAYONNE, *Gascony*. A pretty smart shock was felt.

BLEVILLE, *Normandy*. (a league from *Havre*) About eleven in the morning was observed an oscillation in the waters, from north to south.

BOURDEAUX, capital of *Guienne*. A shock, or rather a repetition of shocks, which lasted some minutes.

CAEN, *Normandy*. A great agitation of the *Orne*.

CHARANTE river, *Angoumois*. A commotion in its waters. See *Angoulesme*.

GAINNEVILLE, *Normandy*. (three leagues from *Havre*) A sensible oscillation of the water.

GARONNE, river, *Guienne*. (near *Bordeaux*) A great agitation of its waters.

HAVRE DE GRACE, *Normandy*. About eleven in the morning, the vessels in this port were strangely tossed.

LYONS, capital of *Lyonois*. Divers shocks felt here, and in the neighbourhood.

ORNE river, *Normandy*, agitated. See *Caen*, and *Ouilly*.

OUILLY, bridge, *Normandy*. (near *Harcourt*) The waters of the *Orne* much agitated, as also those of a lake in this neighbourhood.

IN GERMANY.

BRANSTADT, *Holstein*. The waters were agitated, and the chandeliers in churches were seen to vibrate.

EIDER, river, *Holstein*. An extraordinary commotion of the waters.

ELBE, river. The agitation of the water was sensibly perceived through its whole course.

EMSHORN, *Holstein*. Chandeliers vibrated, and waters were disturbed.

GLUCKSTADT, *Holstein*. An agitation of the waters which lasted several minutes.

HAMBURGH. The *Elbe* strongly agitated.

ITZEOA, *Holstein*. The waters of the *Stohr* rose and fell there, and a large float of timber was thrown several feet on the bank.

OWE river, *Holstein*. See *Utersen*.

KELLINGHAUSEN, *Holstein*. The same phenomena as at *Branstadt* and *Emsborn*.

LIBBESC lake, *Brandenburg*. The water ebbed and flowed six times in half an hour, with a most dreadful noise, the weather being perfectly calm.

LUBEC, *Holstein*. Between eleven and twelve, when the wind was at east, and the air quite calm, an extraordinary agitation of the waters was observed, particularly in the *Trave*, which rose four or five feet perpendicular, as it were all at once, by which motion a merchant ship snapped her cables, and great damage was done to other vessels. The agitation lasted about nine minutes.

308 EARTHQUAKE of

MELDORF, *Holstein*. The like phænomena as at *Emshorn* and *Kellengheusen*.

MUHLGAST lake, *Brandenburg*. The like commotion of the waters as at *Libbesc* lake.

NETZO lake, *Brandenburg*. The like commotion as at *Libbesc* and *Muhlgast* lakes; but here the waters had an insupportable stench.

RENDSBURG, *Holstein*. The congregation at divine service in the new church there, observed three large chandeliers suspended from the roof, to vibrate very much: These weighed twenty hundred each: A lesser one over the baptismal font was not so much affected.

RODDELIN lake, *Brandenburgh*, the like disturbance of the waters, as *Libbesc* and *Muhlgast* lakes.

SAXONY. Shocks felt in several of its mines.

STEINBURGH fort, *Holstein*. In great danger from the violent agitation of the waters which surround it.

STOHR or STOUHR river, *Holstein*. Agitation of its waters. See *Itzeboa*.

STRASBURG, *Alsace*. A shock was felt.

STUTGARD, *Wirtemberg*. A shock was felt.

TEMPLIN lake, *Brandenburg*. The like phænomena as at *Libbesc*, *Muhlgast*, and *Roddelin* lakes.

TRAVE river, *Holstein*. Vast disturbance of its waters. See *Lubec*.

UTERSEN, *Holstein*. A great perturbation in the waters of the *Owe*.

WESER river. Agitations through its whole course.

IN HOLLAND.

ALPHEN. (on the *Rhine*, between *Leyden*, and *Woerden*) In the afternoon, the waters were agitated to such a violent degree, that buoys were broken from their chains, large vessels snapped their cables, smaller ones were thrown out of the water upon the land, and others lying on land were set afloat.

AMSTERDAM. About eleven in the forenoon, the air being perfectly calm, the waters were suddenly agitated in their canals, several boats broke loose, chandeliers were observed to vibrate in the churches, and the mercury which stood pretty high in the barometers descended almost an inch, as it were at once; but no house or other building at land was the least sensibly shaken.

BOIS-LE-DUC. Much the same motion of the waters as at *Amsterdam*.

BOSHOO. Nearly the like phænomena as at *Alphen*.

GOUDA (at the confluence of the rivers *Gouwe* and *Iffel*) Much the same as at *Amsterdam*.

HARLEM (on the river *Sparen*, a league from the sea) In the forenoon, for near four minutes together, not only the water in the rivers, canals, &c. but also all manner of fluids in smaller quantities, as in coolers, tubs, backs, &c. were astonishingly agitated, and dashed over the sides, notwithstanding no motion was perceptible in the containing vessels. In such small quantities also,

the surface of the fluid had apparently a direct ascent, prior to its turbulent motion, and in many places, even the rivers and canals rose twelve inches perpendicular. In *Harlem* meer the course of a vessel, on full sail, was suddenly suspended, and the rudder unhung.

HAGUE. At eleven in the morning, in absolutely calm weather, there was observed of a sudden a slight motion in the water. A tallow-chandler here heard with surprize the clashing noise made by the candles which hung up in his shop; but no motion at all was perceived under foot. In a canal between *Delft* and the *Hague*, the rise was measured to be one foot perpendicular.

HERTOGENBOSCH. See *Bois-le-duc*.

LEERDAM. The like as at *Amsterdam*.

LEYDEN. Between half an hour after ten and eleven in the morning, in some of the canals of this city, the water rose suddenly on the quay, situated on the south. It returned afterwards to its bed, and made several very sensible undulations, so that the boats were strongly agitated: the same motion was perceived here in the water of the backs of two brew-houses.

ROTTERDAM. Besides the like phænomena that were observed at *Alphen*, the chandeliers of the *Roman Catholick* church here, which hung from long iron rods, made several oscillations.

UTRECHT. The like as at *Alphen*.

WOUBROGGE. The like as at *Alphen*.

IN ITALY.

CORSICA island. The sea violently agitated all round it, and most of the rivers in the island overtopped their banks, and drowned much land. In some places a motion of the ground was also felt.

LEMAN lake. The waters retired for some moments at the end of it.

LODI. (in the *Milaneſe*) A ſenſible ſhock.

MILAN city. A motion of the earth felt ſeveral times very ſenſibly.

PIZZIGHITONE (in the *Milaneſe*) Shocks felt.

TURIN, *Savoy*. A violent ſhock.

IN NORWAY.

VIOLENT agitations of ſeveral rivers and lakes.

IN PORTUGAL, and ALGARVE.

THESE kingdoms almoſt univerſally affected, particularly,

BRAGANZA. Much ſhocked and damaged.

CASCAES. (at the mouth of the *Tagus*) Suffered greatly.

COIMBRA. (on the river *Mondego*) About ten in the morning, the ſhocks ſo violent, that the

fine building belonging to the *Jesuits*, which consisted of sixteen separate apartments, was almost entirely destroyed, together with the cathedral, and the church of the Holy Cross.

COLARES. (about twenty miles from *Lisbon*, behind the rock, about two miles from the sea) The thirty-first of *October* the weather was clear, and uncommonly warm for the season; the wind north, from which quarter, about four o'clock in the afternoon, there arose a fog, which came from the sea, and covered the vallies, a thing rare at this season of the year. Soon after, the wind changing to the east, the fog returned to the sea, collecting it self, and becoming exceeding thick. As the fog retired, the sea rose with a prodigious roaring.

The first of *November*, the day broke with a serene sky, the wind continuing at east: But about nine o'clock, the sun began to grow dim, and about half an hour after was heard a rumbling noise, like that of chariots, which increased to such a degree, as to equal that of the loudest cannon; and immediately a shock of an earthquake was felt, which was succeeded by a second and a third; and several light flames of fire issued from the mountains, resembling the kindling of charcoals. In these three shocks the wall of the building moved from east to west. In another situation from whence the sea-coast could be discovered, there issued from one of the hills, called the *Foja*, near the beach of *Adraga*, a great quantity of smoke, very thick, but not very black, which still increased with the fourth shock, and
after

after continued to issue in a greater or less degree. Just as the subterraneous rumblings were heard, it was observed to burst forth at the *Fojo*; and the quantity of the smoke was always proportioned to the noise. The place from whence the smoke was seen to arise, was visited, but it could not be discovered from whence it could have issued, nor could any signs of fire be found near the place: From whence the curious observer infers, either that the smoke exhaled from some eruption or volcano in the sea, which the waters soon covered, or that, if it issued from some chasm in the land, it closed afterwards. He rather inclines to the former opinion, because it is natural, that the water should retire from the place of the eruption. Besides, the sea having risen in some places, it is probable that it fell in others; and indeed it has visibly retired there, for you may walk on the dry shore now, where before you could not wade. And the second conjecture may be true, as some chasms on the dry land are now almost closed up, and others intirely so. In the afternoon preceding the first of *November*, the water of a fountain was greatly decreased: On the morning of the first of *November*, it ran very muddy, and after the earthquake it returned to its usual state, both in quantity and clearness. In some places where there was no water, springs burst forth, which continued to run. On the hills numbers of rocks were split, and there were several rents in the ground, but none considerable: On the coast pieces of rock fell, some of them very large.

Douro river, swelled and overflowed its banks.

ELVAS.

ELVAS. (on the river *Guadiana*) Very much shaken and damaged.

FARO. (a sea-port) A very severe shock, which overthrew a great number of houses, and almost buried the town in its ruins.

GUADIANA river. Most violently agitated. See *Elvas*.

GUIMARANES. (between the *Douro* and the *Minho*) Much shaken.

LAGOS. (a sea-port) Severely shaken, and left uninhabitable.

LAMEGO. (near the *Douro*) Suffered much in the same manner as *Coimbra* and *Elvas*.

LISBON. (a) There was a sensible trembling of the earth in 1750, after which it was excessively dry for four years together, insomuch that some springs, formerly very plentiful of water, were dried, and totally lost; at the same time the predominant winds were east and north-east, accompanied

(a) This city suffered greatly by an earthquake in 1531, thus described by *Paulus Jovius*. hist. l. 29. fol. 180.

“ In the following month of *January*, a like disaster befel
 “ the *Portuguese*, from a sudden expansion of wind in the
 “ bowels of the earth, which had well nigh proved fatal to
 “ the city of *Lisbon*; nor did *Azumbar*, *Santarem* and *Almerin*
 “ fare much better, for a vast number of public edifices and
 “ houses were shaken to pieces and overthrown, and multi-
 “ tudes of the inhabitants buried in the ruins. At the same
 “ time there was a horrid swell of the sea, and several ships
 “ were sucked into the abyss: The waters of the *Tagus* were
 “ driven on its banks, and the bottom left dry in the middle,
 “ to the unspeakable amazement of the beholders. The con-
 “ tinual workings of the earth drove almost all the inhabitants
 “ of the kingdom out of their houses, into the open fields,
 “ where, after the example of the royal family, they lived in
 “ tents, not without frequent apprehensions of being swal-
 “ lowed up by the gaping earth.

panied with various, though very small tremors of the earth. The year 1755, proved very wet and rainy, the summer cooler than usual, and for forty days before the great earthquake, clear weather, yet not remarkably so. The thirty-first of *October*, the atmosphere, and light of the sun had the appearance of clouds, with a notable obfuscation. The first of *November*, early in the morning, a thick fog arose, which was soon dissipated by the heat of the sun, no wind stirring, the sea calm, and the weather as warm as in *England* in *June* or *July*. At thirty-five minutes after nine, without the least warning, except a rumbling noise, not unlike the artificial thunder at our theatres, immediately preceding, a most dreadful earthquake shook by short, but quick vibrations, the foundations of all *Lisbon*, so that many of the tallest edifices fell that instant: Then, with a scarcely perceptible pause, the nature of the motion changed, and every building was tossed like a waggon driven violently over rough stones, which laid in ruins almost every house, church, convent and publick building, with an incredible slaughter of the people. It continued in all about six minutes. At the moment of the beginning, some persons on the river, near a mile from the city, heard their boat make a noise as it run aground or landing, though then in deep water, and saw at the same time the houses falling on both sides the river. Four or five minutes after, the boat made the like noise, which was another shock, which brought down more houses. The bed of the *Tagus* was in many places raised to its surface.

Ships

Ships were drove from their anchors, and jostled together with great violence ; nor did the masters know if they were afloat or aground. The large new quay, called *Cays Depreda*, was overturned, with many hundreds of people on it, and sunk to an unfathomable depth in the water, not so much as one body afterwards appearing. The bar was seen dry from shore to shore ; then suddenly the sea, like a mountain, came rolling in, and about *Belem* castle the water rose fifty feet almost in an instant, and had it not been for the great bay opposite to the city, which received and spread the great flux, the low part of it must have been under water. As it was, it came up to the houses, and drove the inhabitants to the hills. About noon, there was another shock, when the walls of several houses which were yet standing, were seen to open from top to bottom more than a quarter of a yard, but closed again so exactly as to leave scarce any mark of the injury.

This earthquake came on three days before the new moon, when three quarters of the tide had run up. The direction of its progress seems to have been from north to south nearly, for the people on the river, south of the town, observed the remotest buildings to fall first, and the sweep to be continued down to the waters side. Few days passed without some shock for the space of an ensuing year. *October* the tenth, 1756, at eleven at night, there was one which threw down the greatest part of an hotel, in the parish of *St. Andrew*: And *November* the first, 1756, being the anniversary of the fatal tragedy of this unhappy city,

city, another shock gave the inhabitants so terrible a fresh alarm, that they were preparing for their flight into the country; but were prevented by several regiments of horse placed all round by the king's orders.

MONTE	{	ARRABIDA.	} These, being some of			
		ESTRELLA.		} the largest mountains in		
		JULIO.			} <i>Portugal</i> , were impetu-	
		MARVAN.				} ously shaken, as it were
		CINTRA.				

tions, and most of them opened at their summits, split and rent in a wonderful manner, and huge masses of them were thrown down into the subjacent vallies.

Oporto. (near the mouth of the *Douro*) At about forty minutes past nine in the morning, the sky very serene, was heard a dreadful hollow noise like thunder or the rattling of coaches over rugged stones at a distance; and almost at the same instant was felt a severe shock of an earthquake, which lasted six or seven minutes, during which space every thing shook and rattled. It rent several churches, and tumbled down one of the turrets of that of the *Congregadoes*. In the streets the earth was seen to heave under people's feet, as if in labour. The river was also amazingly affected; for in the space of a minute or two, it rose and fell five or six feet, and continued so to do for four hours. It ran up at first with so much violence, that it broke a ship's hawser. Two of the *Brazil* fleet were going out, and had got to the bar, but the sea impetuously forced them back again into the harbour, drove them foul of one

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another,

another, and they narrowly escaped being lost. The river was observed to burst open in some parts, and discharge vast quantities of air; and the agitation was so great in the sea, about a league beyond the bar, that 'tis imagined the air got vent there too. Two other shocks followed this first the same day, but they were short, and much slighter.

PEDRA DE ALVIDAR. (a rock near the hill *Fojo*; see *Colares*) A kind of parapet was broken off from it, which issued from its foundation in the sea.

SANTAREIN. (on the *Tagus*) Suffered much.

SARITHOES and BITURECRAS. Two rocks in the sea near the mouth of the *Tagus*, one of them was broken off at the summit, the other all to pieces.

SETUVAL, SAINT UBAL, or SAINT UBES. (a sea port twenty miles south of *Lisbon*) No traces left of this place, the repeated shocks, and vast surf of the sea having concurred to swallow it up, people and all; which it could the less withstand, as it stood at the head of a little gulph formed by the tide at the mouth of the *Zadaon*. Huge pieces of rock were detached at the same time from the promontory on the west of the town, which consists of a chain of mountains containing fine jasper of different colours.

SILVAS. (four leagues from *Lagos*) Almost entirely destroyed.

TAGUS river, swelled and agitated throughout its whole course, for the space of 300 miles.

VARGE. (on the river *Macaas*) At the time of the earthquake many springs of water burst forth, and some spouted to the height of eighteen or

twenty feet, throwing up sand of various colours, which remained on the ground.

VIANA, (a sea-port at the mouth of the *Lima*) very much damaged.

VILLA NOVA. (two leagues from *Lagos*) Met with almost the same fate as *Faro*.

VILLA REAL (four leagues to the north of *Lamego*) much shattered.

ZIZAMBRE. A mountainous point seven or eight leagues from *Setuval*; which cleft asunder and threw off several vast masses of rock.

IN SPAIN.

FELT all over it, except in *Catalonia*, *Aragon* and *Valencia*, more particularly at

ALGAZAIST. (at the *Streight's* mouth) Several walls fell down, and great part of the town was overflowed.

ANTEQUERA. (on a mountain in *Granada*, five leagues north of *Malaga*) Greatly damaged.

ARCOS. (on the *Guadalete*) Much shattered.

AYAMONTE. (near where the *Guadiana* falls into the bay of *Cadiz*) A little before ten o'clock, immediately upon a hollow rushing noise being heard, a terrible earthquake was felt, which during fourteen or fifteen minutes, damaged almost all the buildings, throwing some down, and leaving others irreparably shattered. In little more than half an hour after, the sea and river, with all their canals, overflowed their bounds with great violence, laying under water all the coasts
of

of the islands adjacent to the city and its neighbourhood, flowing into the very streets. The water rose three times, after it had as many times subsided. One of the swells was at the time of ebb, and visibly with less violence. The water came on in vast black mountains, white with foam at the top, and demolished more than half of the tower at the bar called *de Canala*. The earth was observed to open in several parts, and from the apertures flowed large quantities of water, especially in the maritime places. In the adjacent strands the damage was much greater, as the sea swallowed up all the huts built there, destroying goods and treasure beyond redemption; for all that was overflowed sunk, and the beach became a sea, without the least sign of what it was before. Many persons perished, for although they got aboard some vessels, yet part of these foundered, and others being forced out to sea, the unhappy passengers were so terrified that they threw themselves over-board. The day was serene, and not a breath of wind stirring.

BILBOA. (on the *Nervio*, two leagues from the ocean) A shock and commotion of the waters.

CADIZ. (at the north-west end of the island of *Leon*, opposite to *Port Saint Mary*) Some minutes after nine in the morning, the whole town was shook with a violent earthquake, which lasted about five minutes. The water in the cisterns under ground washed backwards and forwards, so as to make a great froth upon it. At ten minutes after eleven, a wave was seen coming from sea, eight miles off, at least sixty feet higher than common.

common. It dashed against the west part of the town, which is very rocky, and the rocks abated a great deal of its force : At last it came upon the walls, beat in the breast-work, and carried pieces of eight or ten ton weight, forty or fifty yards from the wall, bore away the sand and walls, but left the houses standing, being exceeding strong built. The governor ordered the gates to be shut, that people might not go out of the town, as the land was lower than the town, by which he saved the lives of thousands. When the wave was gone, some parts that are deep at low water, were left quite dry, for the water returned with the same violence it came. At thirty minutes after eleven came a second tide; and these two were followed by four others of the same kind, at eleven o'clock fifty minutes; twelve o'clock thirty minutes; one o'clock ten minutes; and one o'clock fifty minutes. The tides continued, with some intervals, till the evening, but lessening. Every thing was washed off the mole. There was a strong causeway on a very narrow neck of land that goes from the town to the isle of *Leon*, open to the sea on one side, and to the bay on the other, which was washed away, and scarce any mark of it left. About forty or fifty persons, and many cattle that were on it, were all drowned. The ships were exposed to imminent danger; the greatest part of them were driven afloat, but most of them fortunately were saved, some by veering their cables, others by securing themselves by new anchors; so that only one *Swedish* ship, and some boats were

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lost.

loft. The whole day was as clear and ferene as at midsummer, without a breath of wind.

CHICLAN (in the ifle of *Cadiz*) fhocked and overflowed.

CONIL (a fmall port five leagues fouth of *Cadiz*) ruined.

CORDOUA (on the *Guadalquivir*) greatly damaged.

ESCURIAL. (the moft magnificent of the king's palaces, feven leagues north-weft of *Madrid*) Moft terrible fhocks, felt by all the royal family, which occafioned their immediate removal.

ESTAPONA (on the *Mediterranean* fea-coaft, between *Marbella* and *Gibraltar*) the earthquake greatly damaged the church.

GIBRALTAR. (in the *Straits* mouth) About ten minutes after ten, a tremulous motion of the earth was plainly perceived, which lafted about half a minute, then a violent fhock, after that a trembling for five or fix feconds, then another fhock not fo violent as the firft, which went off gradually as it began. It lafted, in the whole, about two minutes. The guns on the battery were feen fome to rife, others to fink, the earth having an undulating motion. Moft people were feized with giddinefs and ficknefs, and fome fell down, others were ftupified, though many that were walking or riding felt no motion, but were fick. The fea rofe fix feet every fifteen minutes, and fell fo low that boats and all the fmall craft near the fhore were left aground, as were numbers of fmall fifh. Ships out in the bay thought they had ftruck upon rocks. This flux and reflux lafted

lasted till next morning, having decreased gradually from two in the afternoon. The day was clear, and but little wind at south-west. *Fahrenheit's* thermometer was at sixty-two, and no alteration was observed.

GRANADA (on the river *Xenil*) damaged considerably.

MADRID. (capital of all *Spain*, on the *Manzanares*) Five minutes after ten in the morning, a great earthquake was very sensibly felt, which lasted about six minutes. Every body at first thought they were seized with a swimming in their heads; and afterwards that the houses in which they were, were falling. The same happened in the churches, so that people trod one another under foot in getting out; and those who observed it in the towers, were very much frightened, thinking that they were tumbling to the ground. It was not felt in coaches, nor, but very little, by those who walked on foot. No remarkable accident happened, excepting that two lads were killed by the falling of a stone cross from the porch of a church belonging to a monastery. St. *Andrews* church was so much shaken, that several apertures remain in the roof and walls; the upper part of the porch of the parish church of St. *Lewis* was split; and those of St. *Philip*, St. *Thomas*, *Portaceli*, and the towers of St. *Trinity* and St. *Millan*, were forced to be examined by skilful workmen.

MALAGA (a sea-port on the *Mediterranean*) felt a violent shock; the bells rung in the stee-

324 EARTHQUAKE of

ples; the water overflowed in a well, and as suddenly retired again.

MEDINA SIDONIA (nine leagues from *Cadiz*) severely shocked.

PORT-REAL. (near *Cadiz*) Much shocked and inundated.

PORT SAINT MARY. (at the mouth of the *Guadalete*) The sea rose and subsided eight several times.

PURVELO. (near *Saint Lucar*) Its steeple and several houses shaken down.

SALAMANCA. (on the *Tormes*, thirty-three leagues north-west of *Madrid*) Shocks felt, and the waters agitated.

SANT LUCAR. (at the mouth of the *Guadalquivir*) Violent shocks, and the sea broke in and did great mischief.

SANT ROQUE. A smart shock which tossed persons out of their seats, and rent an arch of the church.

SEGOVIA. (on the *Elrena*, ten leagues north of *Madrid*) A great commotion of the waters.

SEVILLE. (on the *Guadalquivir*, sixteen leagues above the mouth of it) The earthquake shook down several houses, and greatly damaged some churches, especially the cathedral, the finest in the kingdom, whose famous tower, called *la Giralda*, opened in the four sides, and a great many large stones falling down, killed several persons. The waters were so greatly agitated, that all the vessels in the river were driven ashore.

VALENCIA. (on the *Savar*) Very terrible agitations of the water.

TOLEDO.

TOLEDO (on the *Tagus*, fourteen leagues south of *Madrid*) the river rose ten feet.

XERES (on the *Guadalete*, six leagues north of *Cadiz*) much shaken and damaged.

IN SWEDEN.

THE earthquake was felt in several provinces, and all the rivers and lakes were strongly agitated, especially in *Dalecarlia*.

DALA river. Its waters overflowed the adjacent fields, and afterwards retired within its bed, with no less rapidity. At the same time a lake a league distant from it, and which had no manner of communication with it, bubbled up with great violence.

FAHLUN. (in *Dalecarlia*) Several strong shocks were felt during the time of divine service.

IN SWISSERLAND.

MANY rivers were suddenly turned muddy without rain.

NEUFCHATEL. Its lake swelled to the height of near two feet above its natural level, for the space of a few hours.

ZURICH. An agitation was perceived in the waters of its lake.

AFRICA.

ALGIERS. Great part of it destroyed.

ARZILA. About ten in the morning the sea came suddenly up, and seven *Moors*, who were out of the town walls, were drowned; the waters came through one of the city gates very far. It rose with such impetuosity, that it lifted up a vessel in the bay, which, at the waters falling down again, it dropped with such force upon the land, that it was broke to pieces; and a boat was found at the distance of two musket-shot within land from the sea.

FEZ. Vast numbers of houses fell down, and a great multitude of people were buried in the ruins.

MEQUINEZ. Two thirds of the houses fell down, and also the convent of the *Franciscan Friers*. Many lives were lost.

MOROCCO. By the falling down of a great number of houses many people lost their lives; and about eight leagues from this city, the earth opened, and swallowed up a village, with all the inhabitants (who were known by the name of the *Sons of Busunba*) to the number of about eight or ten thousand persons, together with their cattle of all sorts, as camels, horses, horned beasts, &c. and soon after the earth closed again, in the same manner as it was before.

SAFFE. Several houses fell down, and the sea came up as far as the great Mosque, which is within

within the city, and at a great distance from the sea.

SALLE. The damage here was very great, near a third part of the houses having been overthrown. The waters came into the city with great rapidity, and at their falling off great quantities of fish were found in the streets, and many persons were drowned: Two ferry-boats were overfet in the river, and all the people on board were also drowned; and a large number of camels that were just then going for *Morocco*, were carried away by the waters.

SARJON hills. One of these was rent in two; one side of which fell upon a large town, where there was the famous sanctuary of their prophet, called *Mulay Teris*; and the other side fell down upon another large town, and both towns and the inhabitants were all buried under the said hill.

SCLOGES. (a place where the *Barbarians* live, not far from *Fez*) A mountain broke open, and a stream issued out as red as blood.

TANGIER. The earthquake began at ten in the morning, and lasted ten or twelve minutes. The trembling of the houses, mosques, &c. was great, and a large projecting part of an old building near the city gate, after three shocks fell down to the ground. The sea came up to the very walls, a thing never seen before, and went down directly with the same rapidity as it rose, as far as the place where the large vessels anchor in the bay, leaving upon the mole a great quantity of sand and fish. These commotions of the sea were repeated eighteen times, and continued till six in the

evening, though not with such violence as at the first time. The fountains were dried up, so that there was no water to be had till night: And as to the shore side, the waters came up half a league in land.

TETUAN. The earthquake began here at the same time as at *Tangier*, but lasted only between seven and eight minutes, during which space the shock was repeated three different times, with such violence, that it was feared the whole city would fall down: It was likewise observed, that the waters of the river *Chico*, on the other side of the city, and those of a fountain, appeared very red.

IN THE ATLANTIC ISLANDS.

ANTIGUA. About the time of the earthquake at *Lisbon*, there was such a sea without the bar of this island, as had not been known in the memory of man; and after it all the water at the wharfs, which used to be six feet, was not two inches.

BARBADOES. About two o'clock in the afternoon, the sea ebbed and flowed in a most surprising manner. It ran over the wharfs and the streets into the houses, and at the old bridge brought up numbers of several sorts of fish. It continued thus ebbing and flowing till ten at night.

MADEIRA. In the city of *Funchal*, thirty-eight minutes past nine in the morning, was perceived a shock of an earthquake; the first notice

whereof was a rumbling noise in the air, like that of empty carriages passing hastily over a stone pavement. The observer felt the floor immediately to move with a tremulous motion, vibrating very quickly: The windows rattled, and the whole house seemed to shake; it lasted more than a minute, during which, the vibrations, though continual, abated and increased twice very sensibly, in point of force: not unlike an eccho from the discharge of a fowling-piece, opposite to a range of mountains, whence the sound has reverberated with reciprocal intensions and remissions. The increase, after the first remission of the shock, was the most intense: The door of the room vibrating to and fro very remarkably then, which it had not done before; neither did it afterwards in the second increase. The noise in the air, which had preceded the shock, continued to accompany it; and lasted some seconds after the motion of the earth had entirely ceased; dying away like a peal of distant thunder rolling through the air. The direction of the shock seemed to be from east to west. At three quarters past eleven, the sea, which was quite calm (it being a fine day and no wind stirring) was observed to retire suddenly some paces; then rising, with a great swell, without the least noise, and as suddenly advancing, overflowed the shore, and entered the city. It rose full fifteen feet perpendicular above high-water mark, although the tide, which ebbs and flows there seven feet, was then at half ebb. The water immediately receded again, and, after having fluctuated four or five times between high-water and low-water mark,

mark, the undulations continually decreasing (not unlike the vibrations of a pendulum) it subsided, and the sea remained calm, as before this phænomenon. The season of the year had been more than ordinary dry; the rains, which generally begin to fall the beginning of *October*, not having then set in. The weather for some weeks preceding the earthquake, had been very fine and clear, but the day previous thereto, (*October*, 31) was very remarkably fair and serene, as was the former part of the day on which it happened: But the afternoon was very dull and dark, the sky being entirely overcast with heavy black clouds; the subsequent day was very fair. The greatest height of *Fahrenheit's* thermometer, the three last days of *October*, and the first of *November* was 69. *November* the second, it rose to 71. The barometer had been stationary several days at 29,28 inch. *November* the second, it rose to 30,1. In the northern part of the island the inundation was more violent, the sea there retiring above one hundred paces at first, and suddenly returning, overflowed the shore, forcing open doors, breaking down the walls of several magazines and storehouses, and carrying away in its recess a considerable quantity of grain and some hundred pipes of wine. Great quantities of fish were left ashore, and in the streets of the village of *Machico*. All this was the effect of one inundation of the sea, which never flowed afterwards so high as high-water mark; although it continued fluctuating there much longer before it subsided, than at *Funchal*, as the fluctuation and swell was much greater

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ter at *Funchal*, than it had been farther to the westward, where, in some places, it was hardly, if at all, perceptible.

SAINT MARTINS. The earthquake slightly felt.

TERCERA. Some shocks felt.

It has been reported that much damage was done in the *Canary* islands, but no particulars have as yet come to hand.

AT SEA, and in the OCEAN.

OFF St. *Lucar*. The captain of the *Nancy* felt his ship so violently shaken, that he thought she had struck the ground; but after heaving the lead overboard, found she was in a great depth of water.

Captain *Clark* from *Denia*, in latitude $36^{\circ}. 24'$. between nine and ten in the morning, had his ship shaken and strained as if she had struck on a rock, so that the seams of the deck opened, and the compass was overturned in the benacle.

The master of a vessel bound to the *American* islands, being in latitude 25° . N. longitude 40° . and writing in his cabin, heard a violent noise, as he imagined, in the steerage; and whilst he was asking what was the matter, the ship was put into a strange agitation, and seemed as if she had been suddenly jerked up, and suspended by a rope fastened to the mast head. He immediately started up with great terror and astonishment, and looking out at the cabin window, plainly discovered land

at

at the distance of about a mile; upon this he hastily ordered the lead to be thrown, supposing the ship might have struck; but coming upon deck, the land he had seen was no more to be found, and he perceived with great amazement a violent current cross the ship's way to the leeward. In about a minute this current returned with great impetuosity, and within a league he saw three craggy pointed rocks, throwing up water of various colours, resembling liquid fire. This phenomenon in about two minutes ended in a black cloud, which ascended very heavily. After it had risen above the horizon, no rock was to be seen; and the agitation of the water soon subsided, tho' the cloud, still ascending, was long visible, the weather being extremely clear.

The captain of a *Dutch* vessel, which had sailed from *St. Ubes*, about eight in the morning, being at a quarter after ten, near a league and a half from mount *Sizembre*, which is about six or seven leagues from *St. Ubes*, felt a violent shock in his ship, and at the same time saw that mountain rend, and several large rocks rowl from it into the sea, with a vast and horrid noise. Immediately after, the sky was covered with a thick fog, occasioned by the fall of the rocks into the water. The shock was repeated at different intervals, till sun-set, at which time he observed a thick smoke at N. N. E. distant seven or eight leagues, and soon after flames, which continued all night. The light of the sun, and the distance intercepted them from his sight next morning.

In

In latitude 38° . N. 10° . $47'$ W. off cape St. Vincent, at half an hour past nine, a ship felt a terrible shock which lasted three minutes, and more shocks till half an hour past eleven, all attended with a growling noise. The sky was serene, and the sea smooth: This was out of soundings.

Between nine and ten in the morning, forty leagues west of the same cape, in a calm sea, another ship was so violently agitated, that the anchors, which were lashed, bounced up, and the men were thrown a foot and an half along the deck; and of a sudden the ship sunk in the water, as low as her main chains. The lead shewed a great depth of water, and the line was tinged of a yellow colour, and smelt of sulphur. This shock lasted about ten minutes, but they felt smaller ones for about twenty-four hours.

Several *Dutch* ships off cape St. Mary, thought they struck aground, and fired guns of distress.

Of the extent of this EARTHQUAKE.

WE have seen that, besides a multitude of other places, it was very sensible in Europe at *Fablun* in *Sweden*, in *Africa* at the capital of the empire of *Morocco*, and in *America* at the island of *Barbadoes*. Between *Fablun* and *Barbadoes* are seventy degrees of a great circle, nearly; between *Barbadoes* and *Morocco* forty-nine, and between *Morocco* and *Fablun* thirty-three of the like degrees: Now these constitute the three sides
of

of a spherical triangle, to which if a well known theorem be applyed, it will be found, that the effects of the earthquake of the first of *November*, one thousand seven hundred and fifty-five, were distributed over very nearly four millions of square *English* miles of the earth's surface: A most astonishing space! and greatly surpassing any thing, of this kind, ever recorded in history.

The E N D.

E R R A T A.

Page 12. line 22. read, ἐνοσίγαστον. p. 22. l. 10. r. doctrines. p. 23. l. 13. r. meteorologies. p. 25. l. 1. r. steam. p. 29. line last but one, for in, r. on. p. 64. l. 31. for If, r. Of. p. 67. l. 14. r. nubigenum. p. 88. l. last but one, r. *Asbestus*. p. 106. l. 25. r. *Varenius*. p. 127. l. 11. r. *Achaia*. p. 250. l. 11. r. the superficial. r. *Camden* throughout.

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