aſphaltes; and, accordingly, this ſea is often termed the *Aſphaltic Lake*. The neighbouring land is impregnated with this bitumen: And many have imagined, that, like the Lake Avernus, no fiſhes could live in it, and that birds were ſuffocated in attempting to fly over it. But ſuch diſmal effects are produced by neither of theſe lakes; for both of them contain fiſhes, the birds fly over them in ſafety, and men bathe in them with impunity.

It is ſaid, that, in Bohemia, there is a lake, which has holes in it ſo deep, that they cannot be ſounded, and that, from theſe holes, there iſſue violent winds which ſweep over all Bohemia, and, in winter, raiſe into the air maſſes of ice of more than 100 pounds weight *. We are likewiſe told of a petrifying lake in Iceland; and Lake Neagh in Ireland poſſeſſes the ſame quality. But theſe petrifications are, doubtleſs, nothing but incruſtations ſimilar to thoſe produced by the waters at Arcueil.

* See Act. Leipſ. anno 1682, p. 246.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XII.

Of the Tides.

WATER, like other fluids, naturally deſcends from the higher to the lower grounds, if not prevented by ſome interpoſed obſtacle; and, after it has occupied the loweſt ſituation, it remains ſmooth and tranquil, unleſs diſturbed by ſome foreign cauſe. All the waters of the ocean are collected in the loweſt places upon the ſurface of the earth; and hence the motions of the ſea muſt proceed from external cauſes. The chief motion is that of the tides, which riſe and fall alternately, and from which reſults a general and perpetual motion, in all ſeas, from eaſt to weſt. Theſe two motions have an invariable relation to the mo-

tions of the moon. During the full and new moons, this motion from eaſt to weſt is moſt remarkable, as well as that of the tides, which ebb and flow, upon moſt coaſts, every $6\frac{1}{2}$ hours: It is always high tide when the moon arrives at the meridian, either above or below the horizon of the place; and it is always ebb or low tide when the moon is at the greateſt diſtance from the meridian, or when it riſes and ſets. The motion from eaſt to weſt is perpetual; becauſe, when the tide is riſing, the whole ocean moves from eaſt to weſt, and puſhes weſtward an immenſe body of water; and the ebbing, or reflux, appears only to be owing to the ſmaller quantity of water which is then impelled towards the weſt. The flux, therefore, ought rather to be regarded as a ſwelling, and the reflux as the ſubſiding of the waters, which, in place of diſturbing the motion from eaſt to weſt, is the cauſe that produces and renders it perpetual; though this motion, for the reaſon already mentioned, is greater during the flux than the reflux.

This motion is attended with the following circumſtances: 1*ſt*, It is more ſenſible at the full and new moon than at the quadratures; it is likewiſe more violent in ſpring and autumn than in any other ſeaſon; and it is weakeſt at the ſolſtices. This phænomenon is occaſioned by the combined attractions of the moon and ſun. 2*d*, The direction and quantity of this motion is

is often varied by the winds, eſpecially ſuch as blow conſtantly from the ſame quarter. Great rivers, in like manner, by diſcharging their water into the ſea, produce currents which often extend ſeveral leagues, and are ſtrongeſt when the direction of the wind correſponds with the general motion. Of this an example is afforded in the Pacific Ocean, where the motion from eaſt to weſt is conſtant, and very perceptible. 3*d*, It is worthy of remark, that, when one part of a fluid is moved, the motion is communicated to the whole: During the tides, therefore, a great part of the ocean is ſenſibly put in motion; and, conſequently, the whole ocean, from ſurface to bottom, is moved at the ſame time.

To render this more clear, let us attend to the cauſes which produce the tides. We formerly remarked, that the moon acted upon the earth by a force which ſome call attraction, and others gravity. This force penetrates the whole globe, is exactly proportioned to the quantity of matter, and decreaſes as the ſquares of the diſtances increaſe. Let us next examine what effects this force muſt produce upon the waters, when the moon comes to the meridian of any place. The ſurface of the water immediately under the moon is then nearer that planet than any other part of the earth; of courſe, that part of the ſea muſt be elevated towards the moon, and the ſummit of this eminence muſt be oppoſite to the moon's centre. To produce this eminence, the

waters upon the ſurface, as well as thoſe at the bottom, contribute their ſhare, in proportion to their diſtances from the moon, which acts upon them in the inverſe ratio of the ſquares of their diſtances. Thus the ſurface of this part of the ſea is firſt elevated; the ſurface of the adjacent parts is likewiſe elevated, but in a ſmaller degree; and the waters at the bottom of all theſe parts are raiſed by the ſame cauſe. Hence, as the whole portion of water under the moon is raiſed, the waters at a diſtance, upon which no attraction is exerted, muſt neceſſarily ruſh forward with precipitation to ſupply the place of thoſe which are elevated, or drawn towards the moon. It is in this manner that the flux, or high tide, is produced, which is more or leſs ſenſible on different coaſts, and which agitates the ſea not only at the ſurface, but at the greateſt depths. The reflux, or ebb, is a conſequence of the natural diſpoſition of the water, which, when no longer acted upon by the moon, ſubſides, and returns to occupy thoſe ſhores from which it had been forced to retire by a foreign power. The ſame effect is produced when the moon arrives at the antipode, or oppoſite meridian, but for a different reaſon: In the firſt caſe, the waters riſe, becauſe they are nearer the moon than any other part of the globe; and in the ſecond, they riſe, becauſe the moon is at the greateſt diſtance from them. It is eaſy to perceive that the effect muſt be the ſame; for, the waters here being

ing leſs attracted than thoſe of the oppoſite hemiſphere, they will neceſſarily recede, and form an eminence, the higheſt point of which will be where the attraction is leaſt, that is, in the meridian oppoſite to the moon's ſtation, or to the place where ſhe was thirteen hours before. When the moon comes to the horizon, the tide is ebb, and the ſea is in its natural ſtate of equilibrium. But, when ſhe is in the oppoſite meridian, this equilibrium cannot exiſt; for the waters, at the place oppoſite to the moon, being then at their great diſtance from her, they are leſs attracted than the reſt of the globe; and hence their relative gravity, by which they are conſtantly kept in equilibrium, puſhes them towards the point oppoſite to the moon, in order to preſerve this equilibrium. Thus, in both caſes, when the moon is in the meridian of a place, or in the oppoſite meridian, the waters muſt be elevated nearly to the ſame height; and, conſequently, they muſt ebb or flow back when the moon is in the horizon, either at her riſing or ſetting. A motion, ſuch as we have deſcribed, neceſſarily agitates the whole maſs of the ocean, from its ſurface to its bottom; and, as the bottom is leſs affected by winds than the ſurface, the motion produced in the former, by the tides, is more regular and uniform.

From this alternate ebbing and flowing, there reſults, as already remarked, a conſtant motion of the ſea from eaſt to weſt; for the moon, which

which is the cauſe of the tides, moves from eaſt to weſt, and, by acting ſucceſſively in this direction, ſhe draws the waters after her. This motion is moſt perceptible in ſtraits. At the ſtraits of Magellan, for example, the tides riſe near 20 feet, and they continue at this height ſix hours; but the reflux, or ebbing, laſts only two hours, and the waters run to the weſt*. This inconteſtibly proves, that the reflux is not equal to the flux, and that, from both there reſults a motion to the weſt, which is ſtronger during the flux than the reflux. It is for this reaſon, that, in open ſeas, at great diſtances from land, the tides are only rendered perceptible by this general current of the waters from eaſt to weſt.

The tides are much higher between the tropics than in any other part of the ocean. They likewiſe riſe higher in places that ſtretch from eaſt to weſt, in long and narrow bays, and upon coaſts which are interrupted with iſlands and promontories. The higheſt known tides take place at one of the mouths of the Indus, where they riſe 30 feet perpendicular. They have alſo a remarkable elevation at Malaya, in the ſtraits of Sunda, in the Red Sea, in Nelſon's bay, at the mouth of the river St. Lawrence, upon the coaſts of China and Japan, at Panama, in the Gulf of Bengal, &c.

* See Narborough's Voyages.

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The ſea's motion, from eaſt to weſt, is moſt obſervable in particular places. Voyagers have often remarked it in ſailing from India to Madagaſcar and Africa. It moves alſo with conſiderable force in the Pacific Ocean, and between the Moluccas and Brazil: But it is moſt violent in ſtraits: The waters are carried from eaſt to weſt, through the ſtraits of Magellan, for example, with ſuch rapidity, that their motion is perceptible, at a great diſtance, in the Atlantic ocean. It was this circumſtance, it is ſaid, that made Magellan conjecture that a ſtrait exiſted by which there was a communication with the two ſeas. In the ſtraits formed by the Manillas, in the channels between the Maldiva iſlands, and in the gulf of Mexico, between Cuba and Jucatan, there is a conſtant current from eaſt to weſt. This motion, in the gulf of Paria, is ſo violent, that its ſtrait is called the *Dragon's Mouth*. It is likewiſe violent in the ſea of Canada, in that of Tartary, and in Waigat's ſtraits, through which it forces enormous maſſes of ice into the northern ſeas. The Pacific ocean runs from eaſt to weſt through the ſtraits of Japan; the ſea of Japan runs towards China; and the Indian ocean runs weſtward through the ſtraits of Java, and other iſlands of India. It is, therefore, evident, that the ſea has a general and uniform motion from eaſt to weſt; and, it is certain, that the Atlantic runs towards America, and that the

Pacific

Pacific ocean flies from it, as is apparent at Cape Current between Lima and Panama*.

In fine, the tides rife and fall alternately in fix hours and a half upon moft coafts, though they happen at different hours, according to the climate, and the pofition of particular lands. Thus the coafts of the fea are perpetually beat by the waves; and each tide carries off from the higher grounds fmall quantities of matter, and depofites them, at a diftance, on the bottom of the ocean. In the fame manner, each tide carries in, and depofites upon low coafts, fand, fhells, and other fea-bodies, which gradually form horizontal ftrata, and give rife to downs, and little hills, fimilar to other hills, both in figure and internal ftructure. Thus the fea is conftantly encroaching upon high coafts, and lofing ground upon thofe that are low; and thefe effects are produced by the tides, and by violent winds.

To give an idea of the violent effects of a ftormy fea againft a high coaft, I fhall relate a fact atteſted by an eye-witnefs, a perfon worthy of the higheft credit. In the largeft of the Orkney iflands, there are coafts compofed of folid rock, above 200 feet high, and nearly perpendicular to the furface of the water. The tides, as is ufual in iflands and promontories, rife very high at this place. But, when a violent wind concurs with the flow of the tide, the agitation of the waters is fo great, that they often rife

* See Varen. Geogr. p. 119.

above

above thefe rocks, and fall down in the form of rain: nay, to this amazing height, gravel, and ftones as large as a man's fift, are raifed from the foot of the rocks.

I myfelf faw, in the port of Leghorn, where the fea is much more tranquil, a tempeft in December 1731, which obliged the mariners to cut off the maſts of their veffels, that were driven, by the violence of the wind, from their anchors in the road: the waters of the fea furmounted fortifications of a great height; and as I was upon one of the moft advanced works, before I could reach the town, I was more drenched with fea-water than I could have been by the heavieft rain.

Thefe examples may convey a notion of the violence with which the fea acts againft particular coafts. This conftant agitation gradually wears*, corrodes, excavates, and diminifhes the quantity of the land. All thefe materials are tranſported and depofited in places where the fea is more tranquil. In the time of ftorms, the water is foul and muddy, by the admixture of matters detached from the coafts and from the bottom of the fea. Thefe bodies, which are very vari-

* We are told by Shaw, in his travels, that, in many parts on the coaft of Syria and Phœnicia, the rocks had been cut, by the ancients, into troughs of two or three yards long, and broad in proportion, for the purpofe of making falt by evaporation. But, notwithftanding the hardnefs of the rocks, thefe troughs are now almoft totally obliterated by the agitation of the waves.

ous,

ous, and carried from great diſtances, are thrown upon the low ſhores, eſpecially after tempeſts, as ambergris on the weſt of Ireland, yellow amber upon the coaſts of Pomerania, cocoas upon the coaſts of India, &c. and ſometimes pumice, and other ſingular ſtones. On this occaſion, we may quote a paſſage from the New Voyages to the iſlands of America. 'When at St. Domingo,' ſays the author, 'I was preſented, among other 'things, with ſome light ſtones, brought in by 'the ſea in high ſouth winds: ſome of them 'were two and a half feet long, 18 inches broad, 'and about a foot thick; and yet they weighed 'not above five pounds. They were as white 'as ſnow, harder than pumice, of a fine grain, 'and appeared not to be porous. When, how-'ever, they were thrown into water, they re-'bounded like a foot-ball thrown againſt the 'ground. It was difficult to force them under 'water with the hand. I incloſed two of theſe 'ſtones with thin boards, and found that they 'bore 160 pounds without ſinking. They ſerved 'my negro for a ſhallop on which he divert-'ed himſelf in ſailing about the quay*.' This ſtone muſt have been a pumice of a cloſe fine grain, which had been tranſported by the ſea from the neighbourhood of ſome volcano, in the ſame manner as ambergris, cocoas, common pumice, the ſeeds of plants, reeds, &c. are tranſported. It is chiefly on the coaſts of Ireland

* Tom. i. p. 260.

and

and of Scotland that obſervations of this kind have been made. The ſea, by its general motion from eaſt to weſt, ought to carry to America the productions of our coaſts; and it muſt be by the operation of ſome irregular movements, that the productions of the Eaſt and Weſt Indies, and of the northern regions, are brought upon our coaſts. The winds are probably the cauſe of theſe effects. In open ſeas, and at great diſtances from land, large portions of the water have been ſeen totally covered with pumice-ſtones. They could only come from volcanos in iſlands, or on the continent; and they have probably been tranſported to the open ſeas by currents. Before the ſouth part of America was diſcovered, and when it was not believed that the Indian ocean had any communication with ours, appearances of this kind firſt gave riſe to the ſuſpicion that ſuch a communication was not impoſſible.

The alternate motion of the tides, and the uniform motion of the ſea from eaſt to weſt, exhibit different appearances in different climates, according to the various indentations in the land, and the height of the coaſts. In ſome places the motion from eaſt to weſt is not perceptible; at others, it moves in a contrary direction, as on the coaſt of Guinea. But theſe contrary motions are occaſioned by the winds, by the poſition of the land, by the waters of great rivers, and by the diſpoſition of the bottom of

the

the ſea. All theſe cauſes produce currents, which often change the direction of the general movement. But, as this motion from eaſt to weſt is the greateſt, moſt general, and conſtant, it ought to produce the moſt ſignal effects; and upon the whole, the ſea muſt gradually gain ground on the weſt, and loſe it on the eaſt; and although, upon coaſts where the weſt wind blows during the greateſt part of the year, as in France and Britain, the ſea may gain land on the eaſt, yet theſe exceptions deſtroy not the effect of the general cauſe.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XIII.

Of Inequalities in the Bottom of the Sea, and of Currents.

THE coaſts of the ſea may be divided into three kinds: 1. High coaſts compoſed of hard rocks, commonly perpendicular, and of a conſiderable elevation, riſing ſometimes to the height of 700 or 800 feet. 2. Low coaſts, of which ſome are almoſt level with the ſurface of the water, and others have a ſmall elevation, and are often bordered with rocks nearly of a level with the water, which give riſe to breakers, and render the approach of ſhips exceedingly dangerous. 3. Downs, or coaſts formed by ſand, either accumulated by the ſea, or brought down and depoſited by rivers: theſe downs