stratified rocks, because from the summits of the banks, down to the river the correspondence of the strata in the rocks is visible on either side of the river. That the stratified stones of the mountains are all layers of clay, deposited one above the other by the various floods of the rivers. That the different size of the strata is caused by the difference in the floods--that is to say greater or lesser floods.

981.

The summits of mountains for a long time rise constantly.

The opposite sides of the mountains always approach each other below; the depths of the valleys which are above the sphere of the waters are in the course of time constantly getting nearer to the centre of the world.

In an equal period, the valleys sink much more than the mountains rise.

The bases of the mountains always come closer together.

In proportion as the valleys become deeper, the more quickly are their sides worn away.

982.

In every concavity at the summit of the mountains we shall always find the divisions of the strata in the rocks.

983.

OF THE SEA WHICH ENCIRCLES THE EARTH.

I find that of old, the state of the earth was that its plains were all covered up and hidden by salt water. [Footnote: This passage has already been published by Dr. M. JORDAN: Das Malerbuch des L. da Vinci, Leipzig 1873, p. 86. However, his reading of the text differs from mine.]

The authorities for the study of the structure of the earth.

984.

Since things are much more ancient than letters, it is no marvel if, in our day, no records exist of these seas having covered so many countries; and if, moreover, some records had existed, war and conflagrations, the deluge of waters, the changes of languages and of laws have consumed every thing ancient. But sufficient for us is the testimony of things created in the salt waters, and found again in high mountains far from the seas.

VI.

GEOLOGICAL PROBLEMS.

985.

In this work you have first to prove that the shells at a thousand braccia of elevation were not carried there by the deluge, because they are seen to be all at one level, and many mountains are seen to be above that level; and to inquire whether the deluge was caused by rain or by the swelling of the sea; and then you must show how, neither by rain nor by swelling of the rivers, nor by the overflow of this sea, could the shells--being heavy objects--be floated up the mountains by the sea, nor have carried there by the rivers against the course of their waters.

Doubts about the deluge.

986.

A DOUBTFUL POINT.

Here a doubt arises, and that is: whether the deluge, which happened at the time of Noah, was universal or not. And it would seem not, for the reasons now to be given: We have it in the Bible that this deluge lasted 40 days and 40 nights of incessant and universal rain,

and that this rain rose to ten cubits above the highest mountains in the world. And if it had been that the rain was universal, it would have covered our globe which is spherical in form. And this spherical surface is equally distant in every part, from the centre of its sphere; hence the sphere of the waters being under the same conditions, it is impossible that the water upon it should move, because water, in itself, does not move unless it falls; therefore how could the waters of such a deluge depart, if it is proved that it has no motion? and if it departed how could it move unless it went upwards? Here, then, natural reasons are wanting; hence to remove this doubt it is necessary to call in a miracle to aid us, or else to say that all this water was evaporated by the heat of the sun.

[Footnote: The passages, here given from the MS. Leic., have hitherto remained unknown. Some preliminary notes on the subject are to be found in MS. F 8oa and 8ob; but as compared with the fuller treatment here given, they are, it seems to me, of secondary interest. They contain nothing that is not repeated here more clearly and fully. LIBRI, Histoire des Sciences mathematiques III, pages 218--221, has printed the text of F 80a and 80b, therefore it seemed desirable to give my reasons for not inserting it in this work.]

That marine shells could not go up the mountains.

987.

OF THE DELUGE AND OF MARINE SHELLS.

If you were to say that the shells which are to be seen within the confines of Italy now, in our days, far from the sea and at such heights, had been brought there by the deluge which left them there, I should answer that if you believe that this deluge rose 7 cubits above the highest mountains-- as he who measured it has written--these shells, which always live near the sea-shore, should have been left on the mountains; and not such a little way from the foot of the mountains; nor all at one level, nor in layers upon layers. And if you were to say that these shells are desirous of remaining near to the margin of the sea, and that, as it rose in height, the shells quitted their first home, and followed the increase of the waters up to their highest level; to this I answer, that the cockle is an animal of not more rapid movement than the snail is out of water, or even somewhat slower; because it does not swim, on the contrary it makes a furrow in the sand by means of its sides, and in this furrow it will travel each day from 3 to 4 braccia; therefore this creature, with so slow a motion, could not have travelled from the Adriatic sea as far as Monferrato in Lombardy [Footnote: Monferrato di Lombardia. The range of hills of Monferrato is in Piedmont, and Casale di Monferrato belonged, in Leonardo's time, to the Marchese di Mantova.], which is 250 miles distance, in 40 days; which he has said who took account of the

time. And if you say that the waves carried them there, by their gravity they could not move, excepting at the bottom. And if you will not grant me this, confess at least that they would have to stay at the summits of the highest mountains, in the lakes which are enclosed among the mountains, like the lakes of Lario, or of Como and il Maggiore [Footnote: Lago di Lario. Lacus Larius was the name given by the Romans to the lake of Como. It is evident that it is here a slip of the pen since the the words in the MS. are: "Come Lago di Lario o'l Magare e di Como," In the MS. after line 16 we come upon a digression treating of the weight of water; this has here been omitted. It is 11 lines long.] and of Fiesole, and of Perugia, and others.

And if you should say that the shells were carried by the waves, being empty and dead, I say that where the dead went they were not far removed from the living; for in these mountains living ones are found, which are recognisable by the shells being in pairs; and they are in a layer where there are no dead ones; and a little higher up they are found, where they were thrown by the waves, all the dead ones with their shells separated, near to where the rivers fell into the sea, to a great depth; like the Arno which fell from the Gonfolina near to Monte Lupo [Footnote: Monte Lupo, compare 970, 13; it is between Empoli and Florence.], where it left a deposit of gravel which may still be seen, and which has agglomerated; and of stones of various districts, natures, and colours and hardness, making one single conglomerate. And a little beyond the sandstone

conglomerate a tufa has been formed, where it turned towards Castel Florentino; farther on, the mud was deposited in which the shells lived, and which rose in layers according to the levels at which the turbid Arno flowed into that sea. And from time to time the bottom of the sea was raised, depositing these shells in layers, as may be seen in the cutting at Colle Gonzoli, laid open by the Arno which is wearing away the base of it; in which cutting the said layers of shells are very plainly to be seen in clay of a bluish colour, and various marine objects are found there. And if the earth of our hemisphere is indeed raised by so much higher than it used to be, it must have become by so much lighter by the waters which it lost through the rift between Gibraltar and Ceuta; and all the more the higher it rose, because the weight of the waters which were thus lost would be added to the earth in the other hemisphere. And if the shells had been carried by the muddy deluge they would have been mixed up, and separated from each other amidst the mud, and not in regular steps and layers-- as we see them now in our time.

The marine shells were not produced away from the sea.

988.

As to those who say that shells existed for a long time and were born at a distance from the sea, from the nature of the place and of the cycles, which can influence a place to produce such creatures--to them it may be answered: such an influence could not

place the animals all on one line, except those of the same sort and age; and not the old with the young, nor some with an operculum and others without their operculum, nor some broken and others whole, nor some filled with sea-sand and large and small fragments of other shells inside the whole shells which remained open; nor the claws of crabs without the rest of their bodies; nor the shells of other species stuck on to them like animals which have moved about on them; since the traces of their track still remain, on the outside, after the manner of worms in the wood which they ate into. Nor would there be found among them the bones and teeth of fish which some call arrows and others serpents' tongues, nor would so many [Footnote: I. Scilla argued against this hypothesis, which was still accepted in his days; see: La vana Speculazione, Napoli 1670.] portions of various animals be found all together if they had not been thrown on the sea shore. And the deluge cannot have carried them there, because things that are heavier than water do not float on the water. But these things could not be at so great a height if they had not been carried there by the water, such a thing being impossible from their weight. In places where the valleys have not been filled with salt sea water shells are never to be seen; as is plainly visible in the great valley of the Arno above Gonfolina; a rock formerly united to Monte Albano, in the form of a very high bank which kept the river pent up, in such a way that before it could flow into the sea, which was afterwards at its foot, it formed two great lakes; of which the first was where we now see the city of Florence together with Prato and Pistoia, and Monte Albano. It

followed the rest of its bank as far as where Serravalle now stands. >From the Val d'Arno upwards, as far as Arezzo, another lake was formed, which discharged its waters into the former lake. It was closed at about the spot where now we see Girone, and occupied the whole of that valley above for a distance of 40 miles in length. This valley received on its bottom all the soil brought down by the turbid waters. And this is still to be seen at the foot of Prato Magno; it there lies very high where the rivers have not worn it away. Across this land are to be seen the deep cuts of the rivers that have passed there, falling from the great mountain of Prato Magno; in these cuts there are no vestiges of any shells or of marine soil. This lake was joined with that of Perugia [Footnote: See PI. CXIII.]

A great quantity of shells are to be seen where the rivers flow into the sea, because on such shores the waters are not so salt owing to the admixture of the fresh water, which is poured into it. Evidence of this is to be seen where, of old, the Appenines poured their rivers into the Adriatic sea; for there in most places great quantities of shells are to be found, among the mountains, together with bluish marine clay; and all the rocks which are torn off in such places are full of shells. The same may be observed to have been done by the Arno when it fell from the rock of Gonfolina into the sea, which was not so very far below; for at that time it was higher than the top of San Miniato al Tedesco, since at the highest summit of this the shores may be seen full of shells and oysters

within its flanks. The shells did not extend towards Val di Nievole, because the fresh waters of the Arno did not extend so far.

That the shells were not carried away from the sea by the deluge, because the waters which came from the earth although they drew the sea towards the earth, were those which struck its depths; because the water which goes down from the earth, has a stronger current than that of the sea, and in consequence is more powerful, and it enters beneath the sea water and stirs the depths and carries with it all sorts of movable objects which are to be found in the earth, such as the above-mentioned shells and other similar things. And in proportion as the water which comes from the land is muddier than sea water it is stronger and heavier than this; therefore I see no way of getting the said shells so far in land, unless they had been born there. If you were to tell me that the river Loire [Footnote: Leonardo has written Era instead of Loera or Loira--perhaps under the mistaken idea that Lo was an article.],which traverses France covers when the sea rises more than eighty miles of country, because it is a district of vast plains, and the sea rises about 20 braccia, and shells are found in this plain at the distance of 80 miles from the sea; here I answer that the flow and ebb in our Mediterranean Sea does not vary so much; for at Genoa it does not rise at all, and at Venice but little, and very little in Africa; and where it varies little it covers but little of the country.

The course of the water of a river always rises higher in a place

where the current is impeded; it behaves as it does where it is reduced in width to pass under the arches of a bridge.

Further researches (989-991).

989.

A CONFUTATION OF THOSE WHO SAY THAT SHELLS MAY HAVE BEEN CARRIED TO A DISTANCE OF MANY DAYS' JOURNEY FROM THE SEA BY THE DELUGE, WHICH WAS SO HIGH AS TO BE ABOVE THOSE HEIGHTS.

I say that the deluge could not carry objects, native to the sea, up to the mountains, unless the sea had already increased so as to create inundations as high up as those places; and this increase could not have occurred because it would cause a vacuum; and if you were to say that the air would rush in there, we have already concluded that what is heavy cannot remain above what is light, whence of necessity we must conclude that this deluge was caused by rain water, so that all these waters ran to the sea, and the sea did not run up the mountains; and as they ran to the sea, they thrust the shells from the shore of the sea and did not draw them to wards themselves. And if you were then to say that the sea, raised by the rain water, had carried these shells to such a height, we have already said that things heavier than water cannot rise upon it, but remain at the bottom of it, and do not move unless by the impact of

the waves. And if you were to say that the waves had carried them to such high spots, we have proved that the waves in a great depth move in a contrary direction at the bottom to the motion at the top, and this is shown by the turbidity of the sea from the earth washed down near its shores. Anything which is lighter than the water moves with the waves, and is left on the highest level of the highest margin of the waves. Anything which is heavier than the water moves, suspended in it, between the surface and the bottom; and from these two conclusions, which will be amply proved in their place, we infer that the waves of the surface cannot convey shells, since they are heavier than water.

If the deluge had to carry shells three hundred and four hundred miles from the sea, it would have carried them mixed with various other natural objects heaped together; and we see at such distances oysters all together, and sea-snails, and cuttlefish, and all the other shells which congregate together, all to be found together and dead; and the solitary shells are found wide apart from each other, as we may see them on sea-shores every day. And if we find oysters of very large shells joined together and among them very many which still have the covering attached, indicating that they were left here by the sea, and still living when the strait of Gibraltar was cut through; there are to be seen, in the mountains of Parma and Piacenza, a multitude of shells and corals, full of holes, and still sticking to the rocks there. When I was making the great horse for Milan, a large sack full was brought to me in my workshop by certain

peasants; these were found in that place and among them were many preserved in their first freshness.

Under ground, and under the foundations of buildings, timbers are found of wrought beams and already black. Such were found in my time in those diggings at Castel Fiorentino. And these had been in that deep place before the sand carried by the Arno into the sea, then covering the plain, had heen raised to such a height; and before the plains of Casentino had been so much lowered, by the earth being constantly carried down from them.

[Footnote: These lines are written in the margin.]

And if you were to say that these shells were created, and were continually being created in such places by the nature of the spot, and of the heavens which might have some influence there, such an opinion cannot exist in a brain of much reason; because here are the years of their growth, numbered on their shells, and there are large and small ones to be seen which could not have grown without food, and could not have fed without motion--and here they could not move
[Footnote: These lines are written in the margin.]

990.

That in the drifts, among one and another, there are still to be found the traces of the worms which crawled upon them when they were

not yet dry. And all marine clays still contain shells, and the shells are petrified together with the clay. From their firmness and unity some persons will have it that these animals were carried up to places remote from the sea by the deluge. Another sect of ignorant persons declare that Nature or Heaven created them in these places by celestial influences, as if in these places we did not also find the bones of fishes which have taken a long time to grow; and as if, we could not count, in the shells of cockles and snails, the years and months of their life, as we do in the horns of bulls and oxen, and in the branches of plants that have never been cut in any part. Besides, having proved by these signs the length of their lives, it is evident, and it must be admitted, that these animals could not live without moving to fetch their food; and we find in them no instrument for penetrating the earth or the rock where we find them enclosed. But how could we find in a large snail shell the fragments and portions of many other sorts of shells, of various sorts, if they had not been thrown there, when dead, by the waves of the sea like the other light objects which it throws on the earth? Why do we find so many fragments and whole shells between layer and layer of stone, if this had not formerly been covered on the shore by a layer of earth thrown up by the sea, and which was afterwards petrified? And if the deluge before mentioned had carried them to these parts of the sea, you might find these shells at the boundary of one drift but not at the boundary between many drifts. We must also account for the winters of the years during which the sea multiplied the drifts of sand and mud brought down by the

neighbouring rivers, by washing down the shores; and if you chose to say that there were several deluges to produce these rifts and the shells among them, you would also have to affirm that such a deluge took place every year. Again, among the fragments of these shells, it must be presumed that in those places there were sea coasts, where all the shells were thrown up, broken, and divided, and never in pairs, since they are found alive in the sea, with two valves, each serving as a lid to the other; and in the drifts of rivers and on the shores of the sea they are found in fragments. And within the limits of the separate strata of rocks they are found, few in number and in pairs like those which were left by the sea, buried alive in the mud, which subsequently dried up and, in time, was petrified.

991.

And if you choose to say that it was the deluge which carried these shells away from the sea for hundreds of miles, this cannot have happened, since that deluge was caused by rain; because rain naturally forces the rivers to rush towards the sea with all the things they carry with them, and not to bear the dead things of the sea shores to the mountains. And if you choose to say that the deluge afterwards rose with its waters above the mountains, the movement of the sea must have been so sluggish in its rise against the currents of the rivers, that it could not have carried, floating upon it, things heavier than itself; and even if it had supported them, in its receding it would have left them strewn about, in

various spots. But how are we to account for the corals which are found every day towards Monte Ferrato in Lombardy, with the holes of the worms in them, sticking to rocks left uncovered by the currents of rivers? These rocks are all covered with stocks and families of oysters, which as we know, never move, but always remain with one of their halves stuck to a rock, and the other they open to feed themselves on the animalcules that swim in the water, which, hoping to find good feeding ground, become the food of these shells. We do not find that the sand mixed with seaweed has been petrified, because the weed which was mingled with it has shrunk away, and this the Po shows us every day in the debris of its banks.

Other problems (992-994).

992.

Why do we find the bones of great fishes and oysters and corals and various other shells and sea-snails on the high summits of mountains by the sea, just as we find them in low seas?

993.

You now have to prove that the shells cannot have originated if not in salt water, almost all being of that sort; and that the shells in Lombardy are at four levels, and thus it is everywhere, having been made at various times. And they all occur in valleys that open

towards the seas.

994.

>From the two lines of shells we are forced to say that the earth indignantly submerged under the sea and so the first layer was made; and then the deluge made the second.

[Footnote: This note is in the early writing of about 1470--1480. On the same sheet are the passages No. 1217 and 1219. Compare also No. 1339. All the foregoing chapters are from Manuscripts of about 1510. This explains the want of connection and the contradiction between this and the foregoing texts.]

VII.

ON THE ATMOSPHERE.

Constituents of the atmosphere.

995.

That the brightness of the air is occasioned by the water which has dissolved itself in it into imperceptible molecules. These, being lighted by the sun from the opposite side, reflect the brightness which is visible in the air; and the azure which is seen in it is

caused by the darkness that is hidden beyond the air. [Footnote: Compare Vol. I, No. 300.]

On the motion of air (996--999).

996.

That the return eddies of wind at the mouth of certain valleys strike upon the waters and scoop them out in a great hollow, whirl the water into the air in the form of a column, and of the colour of a cloud. And I saw this thing happen on a sand bank in the Arno, where the sand was hollowed out to a greater depth than the stature of a man; and with it the gravel was whirled round and flung about for a great space; it appeared in the air in the form of a great bell-tower; and the top spread like the branches of a pine tree, and then it bent at the contact of the direct wind, which passed over from the mountains.

997.

The element of fire acts upon a wave of air in the same way as the air does on water, or as water does on a mass of sand --that is earth; and their motions are in the same proportions as those of the motors acting upon them.

998.

OF MOTION.

I ask whether the true motion of the clouds can be known by the motion of their shadows; and in like manner of the motion of the sun.

999.

To know better the direction of the winds. [Footnote: In connection with this text I may here mention a hygrometer, drawn and probably invented by Leonardo. A facsimile of this is given in Vol. I, p. 297 with the note: 'Modi di pesare l'arie eddi sapere quando s'a arrompere il tepo' (Mode of weighing the air and of knowing when the weather will change); by the sponge "Spugnea" is written.]

The globe an organism.

1000.

Nothing originates in a spot where there is no sentient, vegetable and rational life; feathers grow upon birds and are changed every year; hairs grow upon animals and are changed every year, excepting some parts, like the hairs of the beard in lions, cats and their like. The grass grows in the fields, and the leaves on the trees, and every year they are, in great part, renewed. So that we might

say that the earth has a spirit of growth; that its flesh is the soil, its bones the arrangement and connection of the rocks of which the mountains are composed, its cartilage the tufa, and its blood the springs of water. The pool of blood which lies round the heart is the ocean, and its breathing, and the increase and decrease of the blood in the pulses, is represented in the earth by the flow and ebb of the sea; and the heat of the spirit of the world is the fire which pervades the earth, and the seat of the vegetative soul is in the fires, which in many parts of the earth find vent in baths and mines of sulphur, and in volcanoes, as at Mount Aetna in Sicily, and in many other places.

[Footnote: Compare No. 929.]

XVII.

Topographical Notes.

A large part of the texts published in this section might perhaps have found their proper place in connection with the foregoing chapters on Physical Geography. But these observations on Physical Geography, of whatever kind they may be, as soon as they are localised acquire a special interest and importance and particularly as bearing on the question whether Leonardo himself made the observations recorded at the places mentioned or merely noted the statements from hearsay. In a few instances he himself tells us that

he writes at second hand. In some cases again, although the style and expressions used make it seem highly probable that he has derived his information from others-- though, as it seems to me, these cases are not very numerous--we find, on the other hand, among these topographical notes a great number of observations, about which it is extremely difficult to form a decided opinion. Of what the Master's life and travels may have been throughout his sixty-seven years of life we know comparatively little; for a long course of time, and particularly from about 1482 to 1486, we do not even know with certainty that he was living in Italy. Thus, from a biographical point of view a very great interest attaches to some of the topographical notes, and for this reason it seemed that it would add to their value to arrange them in a group by themselves. Leonardo's intimate knowledge with places, some of which were certainly remote from his native home, are of importance as contributing to decide the still open question as to the extent of Leonardo's travels. We shall find in these notes a confirmation of the view, that the MSS. in which the Topographical Notes occur are in only a very few instances such diaries as may have been in use during a journey. These notes are mostly found in the MSS. books of his later and quieter years, and it is certainly remarkable that Leonardo is very reticent as to the authorities from whom he quotes his facts and observations: For instance, as to the Straits of Gibraltar, the Nile, the Taurus Mountains and the Tigris and Euphrates. Is it likely that he, who declared that in all scientific research, his own experience should be the foundation of his

statements (see XIX Philosophy No. 987--991,) should here have made an exception to this rule without mentioning it?

As for instance in the discussion as to the equilibrium of the mass of water in the Mediterranean Sea--a subject which, it may be observed, had at that time attracted the interest and study of hardly any other observer. The acute remarks, in Nos. 985--993, on the presence of shells at the tops of mountains, suffice to prove--as it seems to me--that it was not in his nature to allow himself to be betrayed into wide generalisations, extending beyond the limits of his own investigations, even by such brilliant results of personal study.

Most of these Topographical Notes, though suggesting very careful and thorough research, do not however, as has been said, afford necessarily indisputable evidence that that research was Leonardo's own. But it must be granted that in more than one instance probability is in favour of this idea.

Among the passages which treat somewhat fully of the topography of Eastern places by far the most interesting is a description of the Taurus Mountains; but as this text is written in the style of a formal report and, in the original, is associated with certain letters which give us the history of its origin, I have thought it best not to sever it from that connection. It will be found under No. XXI (Letters).

That Florence, and its neighbourhood, where Leonardo spent his early years, should be nowhere mentioned except in connection with the projects for canals, which occupied his attention for some short time during the first ten years of the XVIth century, need not surprise us. The various passages relating to the construction of canals in Tuscany, which are put together at the beginning, are immediately followed by those which deal with schemes for canals in Lombardy; and after these come notes on the city and vicinity of Milan as well as on the lakes of North Italy.

The notes on some towns of Central Italy which Leonardo visited in 1502, when in the service of Cesare Borgia, are reproduced here in the same order as in the note book used during these travels (MS. L., Institut de France). These notes have but little interest in themselves excepting as suggesting his itinerary. The maps of the districts drawn by Leonardo at the time are more valuable (see No. 1054 note). The names on these maps are not written from right to left, but in the usual manner, and we are permitted to infer that they were made in obedience to some command, possibly for the use of Cesare Borgia himself; the fact that they remained nevertheless in Leonardo's hands is not surprising when we remember the sudden political changes and warlike events of the period. There can be no doubt that these maps, which are here published for the first time, are original in the strictest sense of the word, that is to say drawn from observations of the places themselves; this is proved by

the fact--among others--that we find among his manuscripts not only the finished maps themselves but the rough sketches and studies for them. And it would perhaps be difficult to point out among the abundant contributions to geographical knowledge published during the XVIth century, any maps at all approaching these in accuracy and finish.

The interesting map of the world, so far as it was then known, which is among the Leonardo MSS. at Windsor (published in the 'Archaeologia' Vol. XI) cannot be attributed to the Master, as the Marchese Girolamo d'Adda has sufficiently proved; it has not therefore been reproduced here.

Such of Leonardo's observations on places in Italy as were made before or after his official travels as military engineer to Cesare Borgia, have been arranged in alphabetical order, under Nos. 1034-1054. The most interesting are those which relate to the Alps and the Appenines, Nos. 1057-1068.

Most of the passages in which France is mentioned have hitherto remained unknown, as well as those which treat of the countries bordering on the Mediterranean, which come at the end of this section. Though these may be regarded as of a more questionable importance in their bearing on the biography of the Master than those which mention places in France, it must be allowed that they are interesting as showing the prominent place which the countries

of the East held in his geographical studies. He never once alludes to the discovery of America.

I.

ITALY.

Canals in connection with the Arno (1001-1008).

1001.

CANAL OF FLORENCE.

Sluices should be made in the valley of la Chiana at Arezzo, so that when, in the summer, the Arno lacks water, the canal may not remain dry: and let this canal be 20 braccia wide at the bottom, and at the top 30, and 2 braccia deep, or 4, so that two of these braccia may flow to the mills and the meadows, which will benefit the country; and Prato, Pistoia and Pisa, as well as Florence, will gain two hundred thousand ducats a year, and will lend a hand and money to this useful work; and the Lucchese the same, for the lake of Sesto will be navigable; I shall direct it to Prato and Pistoia, and cut through Serravalle and make an issue into the lake; for there will be no need of locks or supports, which are not lasting and so will always be giving trouble in working at them and keeping them up.

And know that in digging this canal where it is 4 braccia deep, it will cost 4 dinari the square braccio; for twice the depth 6 dinari, if you are making 4 braccia [Footnote: This passage is illustrated by a slightly sketched map, on which these places are indicated from West to East: Pisa, Luccha, Lago, Seravalle, Pistoja, Prato, Firenze.] and there are but 2 banks; that is to say one from the bottom of the trench to the surface of the edges of it, and the other from these edges to the top of the ridge of earth which will be raised on the margin of the bank. And if this bank were of double the depth only the first bank will be increased, that is 4 braccia increased by half the first cost; that is to say that if at first 4 dinari were paid for 2 banks, for 3 it would come to 6, at 2 dinari the bank, if the trench measured 16 braccia at the bottom; again, if the trench were 16 braccia wide and 4 deep, coming to 4 lire for the work, 4 Milan dinari the square braccio; a trench which was 32 braccia at the bottom would come to 8 dinari the square braccio.

1002.

>From the wall of the Arno at [the gate of] la Giustizia to the bank of the Arno at Sardigna where the walls are, to the mills, is 7400 braccia, that is 2 miles and 1400 braccia and beyond the Arno is 5500 braccia.

[Footnote: 2. Giustizia. By this the Porta della Giustizia seems to be meant; from the XVth to the XVIth centuries it was also

commonly known as Porta Guelfa, Porta San Francesco del Renaio, Porta Nuova, and Porta Reale. It was close to the Arno opposite to the Porta San Niccolo, which still exists.]

1003.

By guiding the Arno above and below a treasure will be found in each acre of ground by whomsoever will.

1004.

The wall of the old houses runs towards the gate of San Nicolo.

[Footnote: By the side of this text there is an indistinct sketch, resembling that given under No.973. On the bank is written the word Casace. There then follows in the original a passage of 12 lines in which the consequences of the windings of the river are discussed. A larger but equally hasty diagram on the same page represents the shores of the Arno inside Florence as in two parallel lines. Four horizontal lines indicate the bridges. By the side these measures are stated in figures: I. (at the Ponte alla Carraja): 230--largho br. 12 e 2 di spoda e 14 di pile e a 4 pilastri; 2. (at the Ponte S. Trinita); l88--largho br. 15 e 2 di spode he 28 di pilastri for delle spode e pilastri so 2; 3. (at the Ponte vecchio); pote lung br. 152 e largo; 4. (at the Ponte alle Grazie): 290 ellargo 12 e 2 di spode e 6 di pili.

There is, in MS. W. L. 212b, a sketched plan of Florence, with the following names of gates:
Nicholo--Saminiato--Giorgo--Ghanolini--Porta San Fredian
--Prato--Faenza--Ghallo--Pinti--Giustitia.]

1005.

The ruined wall is 640 braccia; 130 is the wall remaining with the mill; 300 braccia were broken in 4 years by Bisarno.

1006.

They do not know why the Arno will never remain in a channel. It is because the rivers which flow into it deposit earth where they enter, and wear it away on the opposite side, bending the river in that direction. The Arno flows for 6 miles between la Caprona and Leghorn; and for 12 through the marshes, which extend 32 miles, and 16 from La Caprona up the river, which makes 48; by the Arno from Florence beyond 16 miles; to Vico 16 miles, and the canal is 5; from Florence to Fucechio it is 40 miles by the river Arno.

56 miles by the Arno from Florence to Vico; by the Pistoia canal it is 44 miles. Thus it is 12 miles shorter by the canal than by the Arno.

[Footnote: This passage is written by the side of a map washed in Indian ink, of the course of the Arno; it is evidently a sketch for a completer map.

These investigations may possibly be connected with the following documents. Francesco Guiducci alla Balia di Firenze. Dal Campo contro Pisa 24 Luglio 1503 (Archivio di Stato, Firenze, Lettere alla Balia; published by J. GAYE, Carteggio inedito d'Artisti, Firenze 1840, Tom. II, p. 62): Ex Castris, Franciscus Ghuiduccius, 24. Jul. 1503. Appresso fu qui hieri con una di V. Signoria Alexandro degli Albizi insieme con Leonardo da Vinci et certi altri, et veduto el disegno insieme con el ghovernatore, doppo molte discussioni et dubii conclusesi che l'opera fussi molto al proposito, o si veramente Arno volgersi qui, o restarvi con un canale, che almeno vieterebbe che le colline da nemici non potrebbono essere offese; come tucto referiranno loro a bocha V. S.

And, Archivio di Stato, Firenze, Libro d'Entrata e Uscita di cassa de' Magnifici Signori di luglio e agosto

1503 a 51 T.: Andata di Leonardo al Campo sotto Pisa. Spese extraordinarie dieno dare a di XXVI di luglio L. LVI sol. XII per loro a Giovanni Piffero; e sono per tanti, asegnia avere spexi in vetture di sei chavalli a spese di vitto per andare chon Lionardo da Vinci a livellare Arno in quello di Pisa per levallo del lilo suo. (Published by MILANESI, Archivio Storico Italiano, Serie III, Tom.

XVI.} VASARI asserts: (Leonardo) fu il primo ancora, che giovanetto discorresse sopra il fiume d'Arno per metterlo in canale da Pisa a Fiorenza (ed. SANSONI, IV, 20).

The passage above is in some degree illustrated by the map on Pl. CXII, where the course of the Arno westward from Empoli is shown.]

1007.

The eddy made by the Mensola, when the Arno is low and the Mensola full.

[Footnote: Mensola is a mountain stream which falls into the Arno about a mile and a half above Florence.

A=Arno, I=Isola, M=Mvgone, P=Pesa, N=Mesola.]

1008.

That the river which is to be turned from one place to another must be coaxed and not treated roughly or with violence; and to do this a sort of floodgate should be made in the river, and then lower down one in front of it and in like manner a third, fourth and fifth, so that the river may discharge itself into the channel given to it, or that by this means it may be diverted from the place it has damaged, as was done in Flanders--as I was told by Niccolo di Forsore.

How to protect and repair the banks washed by the water, as below the island of Cocomeri.

Ponte Rubaconte (Fig. 1); below [the palaces] Bisticci and Canigiani (Fig. 2). Above the flood gate of la Giustizia (Fig. 3); a b is a sand bank opposite the end of the island of the Cocomeri in the middle of the Arno (Fig. 4). [Footnote: The course of the river Arno is also discussed in Nos. 987 and 988.]

Canals in the Milanese (1009-1013).

1009.

The canal of San Cristofano at Milan made May 3rd 1509. [Footnote: This observation is written above a washed pen and ink drawing which has been published as Tav. VI in the ,,Saggio." The editors of that work explain the drawing as "uno Studio di bocche per estrazione d'acqua."]

1010.

OF THE CANAL OF MARTESANA.

By making the canal of Martesana the water of the Adda is greatly diminished by its distribution over many districts for the

irrigation of the fields. A remedy for this would be to make several little channels, since the water drunk up by the earth is of no more use to any one, nor mischief neither, because it is taken from no one; and by making these channels the water which before was lost returns again and is once more serviceable and useful to men.

[Footnote: "el navilio di Martagano" is also mentioned in a note written in red chalk, MS. H2 17a Leonardo has, as it seems, little to do with Lodovico il Moro's scheme to render this canal navigable. The canal had been made in 1460 by Bertonino da Novara. Il Moro issued his degree in 1493, but Leonardo's notes about this canal were, with the exception of one (No. 1343), written about sixteen years later.]

1011.

No canal which is fed by a river can be permanent if the river whence it originates is not wholly closed up, like the canal of Martesana which is fed by the Ticino.

1012.

>From the beginning of the canal to the mill.

>From the beginning of the canal of Brivio to the mill of Travaglia is 2794 trabochi, that is 11176 braccia, which is more than 3 miles

and two thirds; and here the canal is 57 braccia higher than the surface of the water of the Adda, giving a fall of two inches in every hundred trabochi; and at that spot we propose to take the opening of our canal.

[Footnote: The following are written on the sketches: At the place marked N: navilio da dacquiue (canal of running water); at M: molin del Travaglia (Mill of Travaglia); at R: rochetta ssanta maria (small rock of Santa Maria); at A: Adda; at L: Lagho di Lecho ringorgato alli 3 corni in Adda,--Concha perpetua (lake of Lecco overflowing at Tre Corni, in Adda,-- a permanent sluice). Near the second sketch, referring to the sluice near Q: qui la chatena ttalie d'u peso (here the chain is in one piece). At M in the lower sketch: mol del travaglia, nel cavare la concha il tereno ara chotrapero co cassa d'acqua. (Mill of Travaglia, in digging out the sluice the soil will have as a counterpoise a vessel of water).]

1013.

If it be not reported there that this is to be a public canal, it will be necessary to pay for the land; [Footnote 3: il re. Louis XII or Francis I of France. It is hardly possible to doubt that the canals here spoken of were intended to be in the Milanese. Compare with this passage the rough copy of a letter by Leonardo, to the

"Presidente dell' Ufficio regolatore dell' acqua" on No. 1350. See also the note to No. 745, 1. 12.] and the king will pay it by remitting the taxes for a year.

Estimates and preparatory studies for canals (1014. 1015).

1014.

CANAL.

The canal which may be 16 braccia wide at the bottom and 20 at the top, we may say is on the average 18 braccia wide, and if it is 4 braccia deep, at 4 dinari the square braccia; it will only cost 900 ducats, to excavate by the mile, if the square braccio is calculated in ordinary braccia; but if the braccia are those used in measuring land, of which every 4 are equal to 4 1/2 and if by the mile we understand three thousand ordinary braccia; turned into land braccia, these 3000 braccia will lack 1/4; there remain 2250 braccia, which at 4 dinari the braccio will amount to 675 ducats a mile. At 3 dinari the square braccio, the mile will amount to 506 1/4 ducats so that the excavation of 30 miles of the canal will amount to 15187 1/2 ducats.

1015.

To make the great canal, first make the smaller one and conduct into

it the waters which by a wheel will help to fill the great one.

Notes on buildings in Milan (1016-1019)

1016.

Indicate the centre of Milan.

Moforte--porta resa--porta nova--strada nova--navilio--porta cumana--barco--porta giovia--porta vercellina--porta sco Anbrogio--porta Tesinese--torre dell' Imperatore-- porta Lodovica--acqua.

[Footnote: See Pl. CIX. The original sketch is here reduced to about half its size. The gates of the town are here named, beginning at the right hand and following the curved line. In the bird's eye view of Milan below, the cathedral is plainly recognisable in the middle; to the right is the tower of San Gottardo. The square, above the number 9147, is the Lazzaretto, which was begun in 1488. On the left the group of buildings of the 'Castello' will be noticed. On the sketched Plan of Florence (see No. 1004 note) Leonardo has written on the margin the following names of gates of Milan: Vercellina --Ticinese--Ludovica--Romana--Orientale-- Nova--Beatrice--Cumana--Compare too No. 1448, 11. 5, 12.]

1017.

The moat of Milan.

Canal 2 braccia wide.

The castle with the moats full.

The filling of the moats of the Castle of Milan.

1018.

THE BATH.

To heat the water for the stove of the Duchess take four parts of cold water to three parts of hot water.

[Footnote: Duchessa di Milano, Beatrice d'Este, wife of Ludovico il Moro to whom she was married, in 1491. She died in June 1497.]

1019.

In the Cathedral at the pulley of the nail of the cross.

Item.

To place the mass v r in the...

[Footnote: On this passage AMORETTI remarks (Memorie Storiche chap. IX): Nell'anno stesso lo veggiamo formare un congegno di carucole e di corde, con cui trasportare in piu venerabile e piu sicuro luogo, cioe nell'ultima arcata della nave di mezzo della metropolitana, la sacra reliquia del Santo Chiodo, che ivi ancor si venera. Al fol. 15 del codice segnato Q. R. in 16, egli ci ha lasciata di tal congegno una doppia figura, cioe una di quattro carucole, e una di tre colle rispettive corde, soggiugnandovi: in Domo alla carucola del Chiodo della Croce.

AMORETTI'S views as to the mark on the MS, and the date when it was written are, it may be observed, wholly unfounded. The MS. L, in which it occurs, is of the year 1502, and it is very unlikely that Leonardo was in Milan at that time; this however would not prevent the remark, which is somewhat obscure, from applying to the Cathedral at Milan.]

1020.

OF THE FORCE OF THE VACUUM FORMED IN A MOMENT.

I saw, at Milan, a thunderbolt fall on the tower della Credenza on its Northern side, and it descended with a slow motion down that side, and then at once parted from that tower and carried with it and tore away from that wall a space of 3 braccia wide and two deep;

and this wall was 4 braccia thick and was built of thin and small old bricks; and this was dragged out by the vacuum which the flame of the thunderbolt had caused, &c.

[Footnote: With reference to buildings at Milan see also Nos. 751 and 756, and Pl. XCV, No. 2 (explained on p. 52), Pl. C (explained on pages 60-62). See also pages 25, 39 and 40.]

Remarks on natural phenomena in and near Milan (1021. 1022).

1021.

I have already been to see a great variety (of atmospheric effects). And lately over Milan towards Lago Maggiore I saw a cloud in the form of an immense mountain full of rifts of glowing light, because the rays of the sun, which was already close to the horizon and red, tinged the cloud with its own hue. And this cloud attracted to it all the little clouds that were near while the large one did not move from its place; thus it retained on its summit the reflection of the sunlight till an hour and a half after sunset, so immensely large was it; and about two hours after sunset such a violent wind arose, that it was really tremendous and unheard of.

[Footnote: di arie is wanting in the original but may safely be inserted in the context, as the formation of clouds is under discussion before this text.]

1022.

On the 10th day of December at 9 o'clock a. m. fire was set to the place.

On the l8th day of December 1511 at 9 o'clock a. m. this second fire was kindled by the Swiss at Milan at the place called DCXC.
[Footnote: With these two texts, (l. 1--2 and l. 3--5 are in the original side by side) there are sketches of smoke wreaths in red chalk.]

Note on Pavia.

1023.

The chimneys of the castle of Pavia have 6 rows of openings and from each to the other is one braccio.

[Footnote: Other notes relating to Pavia occur on p. 43 and p. 53 (Pl. XCVIII, No. 3). Compare No. 1448, 26.]

Notes on the Sforzesca near Vigevano (1024-1028).

1024.

On the 2nd day of February 1494. At Sforzesca I drew twenty five steps, 2/3 braccia to each, and 8 braccia wide.

[Footnote: See Pl. CX, No. 2. The rest of the notes on this page refer to the motion of water. On the lower sketch we read: 4 br. (four braccia) and giara (for ghiaja, sand, gravel).]

1025.

The vineyards of Vigevano on the 20th day of March 1494.

[Footnote: On one side there is an effaced sketch in red chalk.]

1026.

To lock up a butteris at Vigevano.

1027.

Again if the lowest part of the bank which lies across the current of the waters is made in deep and wide steps, after the manner of stairs, the waters which, in their course usually fall perpendicularly from the top of such a place to the bottom, and wear away the foundations of this bank can no longer descend with a blow of too great a force; and I find the example of this in the stairs down which the water falls in the fields at Sforzesca at Vigevano

over which the running water falls for a height of 50 braccia.

1028.

Stair of Vigevano below La Sforzesca, 130 steps, 1/4 braccio high and 1/2 braccio wide, down which the water falls, so as not to wear away anything at the end of its fall; by these steps so much soil has come down that it has dried up a pool; that is to say it has filled it up and a pool of great depth has been turned into meadows.

Notes on the North Italian lake. (1029-1033)

1029.

In many places there are streams of water which swell for six hours and ebb for six hours; and I, for my part, have seen one above the lake of Como called Fonte Pliniana, which increases and ebbs, as I have said, in such a way as to turn the stones of two mills; and when it fails it falls so low that it is like looking at water in a deep pit.

[Footnote: The fountain is known by this name to this day: it is near Torno, on the Eastern shore of Como. The waters still rise and fall with the flow and ebb of the tide as Pliny described it (Epist. IV, 30; Hist. Nat. II, 206).]

1030.

LAKE OF COMO. VALLEY OF CHIAVENNA.

Above the lake of Como towards Germany is the valley of Chiavenna where the river Mera flows into this lake. Here are barren and very high mountains, with huge rocks. Among these mountains are to be found the water-birds called gulls. Here grow fir trees, larches and pines. Deer, wildgoats, chamois, and terrible bears. It is impossible to climb them without using hands and feet. The peasants go there at the time of the snows with great snares to make the bears fall down these rocks. These mountains which very closely approach each other are parted by the river. They are to the right and left for the distance of 20 miles throughout of the same nature. >From mile to mile there are good inns. Above on the said river there are waterfalls of 400 braccia in height, which are fine to see; and there is good living at 4 soldi the reckoning. This river brings down a great deal of timber.

VAL SASINA.

Val Sasina runs down towards Italy; this is almost the same form and character. There grow here many mappello and there are great ruins and falls of water [Footnote 14: The meaning of mappello is unknown.].

VALLEY OF INTROZZO.

This valley produces a great quantity of firs, pines and larches; and from here Ambrogio Fereri has his timber brought down; at the head of the Valtellina are the mountains of Bormio, terrible and always covered with snow; marmots (?) are found there.

BELLAGGIO.

Opposite the castle Bellaggio there is the river Latte, which falls from a height of more than 100 braccia from the source whence it springs, perpendicularly, into the lake with an inconceivable roar and noise. This spring flows only in August and September.

VALTELLINA.

Valtellina, as it is called, is a valley enclosed in high and terrible mountains; it produces much strong wine, and there is so much cattle that the natives conclude that more milk than wine grows there. This is the valley through which the Adda passes, which first runs more than 40 miles through Germany; this river breeds the fish temolo which live on silver, of which much is to be found in its sands. In this country every one can sell bread and wine, and the wine is worth at most one soldo the bottle and a pound of veal one soldo, and salt ten dinari and butter the same and their pound is 30 ounces, and eggs are one soldo the lot.

1031.

At BORMIO.

At Bormio are the baths;--About eight miles above Como is the Pliniana, which increases and ebbs every six hours, and its swell supplies water for two mills; and its ebbing makes the spring dry up; two miles higher up there is Nesso, a place where a river falls with great violence into a vast rift in the mountain. These excursions are to be made in the month of May. And the largest bare rocks that are to be found in this part of the country are the mountains of Mandello near to those of Lecco, and of Gravidona towards Bellinzona, 30 miles from Lecco, and those of the valley of Chiavenna; but the greatest of all is that of Mandello, which has at its base an opening towards the lake, which goes down 200 steps, and there at all times is ice and wind.

IN VAL SASINA.

In Val Sasina, between Vimognio and Introbbio, to the right hand, going in by the road to Lecco, is the river Troggia which falls from a very high rock, and as it falls it goes underground and the river ends there. 3 miles farther we find the buildings of the mines of copper and silver near a place called Pra' Santo Pietro, and mines of iron and curious things. La Grigna is the highest mountain there

is in this part, and it is quite bare.

[Footnote: 1030 and 1031. From the character of the handwriting we may conclude that these observations were made in Leonardo's youth; and I should infer from their contents, that they were notes made in anticipation of a visit to the places here described, and derived from some person (unknown to us) who had given him an account of them.]

1032.

The lake of Pusiano flows into the lake of Segrino [Footnote 3: The statement about the lake Segrino is incorrect; it is situated in the Valle Assina, above the lake of Pusiano.] and of Annone and of Sala. The lake of Annone is 22 braccia higher at the surface of its water than the surface of the water of the lake of Lecco, and the lake of Pusiano is 20 braccia higher than the lake of Annone, which added to the afore said 22 braccia make 42 braccia and this is the greatest height of the surface of the lake of Pusiano above the surface of the lake of Lecco.

[Footnote: This text has in the original a slight sketch to illustrate it.]

1033.

At Santa Maria in the Valley of Ravagnate [Footnote 2: Ravagnate (Leonardo writes Ravagna) in the Brianza is between Oggiono and Brivio, South of the lake of Como. M. Ravaisson avails himself of this note to prove his hypothesis that Leonardo paid two visits to France. See Gazette des Beaux Arts, 1881 pag. 528:

Au recto du meme feuillet, on lit encore une note relative a une vallee "nemonti brigatia"; il me semble qu'il s'agit bien des monts de Briancon, le Brigantio des anciens. Briancon est sur la route de Lyon en Italie. Ce fut par le mont Viso que passerent, en aout 1515, les troupes francaises qui allaient remporter la victoire de Marignan.

Leonard de Vinci, ingenieur de Francois Ier, comme il l'avait ete de Louis XII, aurait-il ete pour quelque chose dans le plan du celebre passage des Alpes, qui eut lieu en aout 1515, et a la suite duquel on le vit accompagner partout le chevaleresque vainqueur? Auraitil ete appele par le jeune roi, de Rome ou l'artiste etait alors, des son avenement au trone?] in the mountains of Brianza are the rods of chestnuts of 9 braccia and one out of an average of 100 will be 14 braccia.

At Varallo di Ponbia near to Sesto on the Ticino the quinces are white, large and hard.

[Footnote 5: Varallo di Ponbia, about ten miles South of Arona is

distinct from Varallo the chief town in the Val di Sesia.]

Notes on places in Central Italy, visited in 1502 (1034-1054).

1034.

Pigeon-house at Urbino, the 30th day of July 1502. [Footnote: An indistinct sketch is introduced with this text, in the original, in which the word Scolatoro (conduit) is written.]

1035.

Made by the sea at Piombino. [Footnote: Below the sketch there are eleven lines of text referring to the motion of waves.]

1036.

Acquapendente is near Orvieto. [Footnote: Acquapendente is about 10 miles West of Orvieto, and is to the right in the map on Pl. CXIII, near the lake of Bolsena.]

1037.

The rock of Cesena. [Footnote: See Pl. XCIV No. 1, the lower sketch. The explanation of the upper sketch is given on p. 29.]

1038.

Siena, a b 4 braccia, a c 10 braccia. Steps at [the castle of] Urbino. [Footnote: See Pl. CX No. 3; compare also No. 765.]

1039.

The bell of Siena, that is the manner of its movement, and the place of the attachment of the clapper. [Footnote: The text is accompanied by an indistinct sketch.]

1040.

On St. Mary's day in the middle of August, at Cesena, 1502. [Footnote: See Pl. CX, No. 4.]

1041.

Stairs of the [palace of the] Count of Urbino,--rough. [Footnote: The text is accompanied by a slight sketch.]

1042.

At the fair of San Lorenzo at Cesena. 1502.

1043.

Windows at Cesena. [Footnote: There are four more lines of text which refer to a slightly sketched diagram.]

1044.

At Porto Cesenatico, on the 6th of September 1502 at 9 o'clock a. m.

The way in which bastions ought to project beyond the walls of the towers to defend the outer talus; so that they may not be taken by artillery.

[Footnote: An indistinct sketch, accompanies this passage.]

1045.

The rock of the harbour of Cesena is four points towards the South West from Cesena.

1046.

In Romagna, the realm of all stupidity, vehicles with four wheels are used, of which O the two in front are small and two high ones are behind; an arrangement which is very unfavourable to the motion, because on the fore wheels more weight is laid than on those behind, as I showed in the first of the 5th on "Elements".

1047.

Thus grapes are carried at Cesena. The number of the diggers of the ditches is [arranged] pyramidically. [Footnote: A sketch, representing a hook to which two bunches of grapes are hanging, refers to these first two lines. Cesena is mentioned again Fol. 82a: Carro da Cesena (a cart from Cesena).]

1048.

There might be a harmony of the different falls of water as you saw them at the fountain of Rimini on the 8th day of August, 1502.

1049.

The fortress at Urbino. [Footnote: 1049. In the original the text is written inside the sketch in the place here marked n.]

1050.

Imola, as regards Bologna, is five points from the West, towards the North West, at a distance of 20 miles.

Castel San Piero is seen from Imola at four points from the West towards the North West, at a distance of 7 miles.