

cies, which grow in cornfields, or meadows, on the road side, and even on the sea shore. The low lands are covered with the same sort of grass as the rest of the country, and serve for pasture to those numerous herds of cattle for which the territory of Molina is famous.

These observations occur in different kingdoms. The mines of Sainte Marie, in France, are covered with oak, fir, apple and pear, cherry and plumb trees, with good pasture and corn, in a soil, about two feet in depth, covering the most sulphurous arsenical rocks, of silver, copper, and lead mines in Europe, where the very veins are often seen above ground. An equal fertility reigns near the mines of Clonsthal, on the mountain of Hartz, belonging to Hanover, with excellent pasture. The same happens on those of Freyberg, in Saxony, that are covered with barley, in June; it being a singular sight, to see a body of people, reaping the corn over the heads of a thousand miners below, busy in digging out passages, and blowing up rocks, full of arsenic, and sulphur. Some mines, without doubt, are found under bare rocks, though this barrenness does not proceed from any mineral vapour, but from different causes, and chiefly, that, moisture, heat, and cold, have more power on some rocks, than over others. This is the case with the great mountain of Rammelsberg, at the foot

of which stands the imperial city of Gollar, so famous for its silver mines, where the loosened stone may be observed to crumble away, and be covered with moss, and verdure: insomuch that though the period is not yet arrived, for its entire decomposition, soon, or late, it will happen, and be covered with grass, in the same manner as the mountain of Hartz is at present.

✦ About a quarter of a league from the city of Molina, there is a spring whose waters have a smell like rotten eggs, from being impregnated with sulphur and alkali: those who have analyzed them, assure us, that they are of the same nature with the springs near Gibraltar, and the waters of Cotterets, in France, and equally useful in cutaneous complaints. The river Gallo abounds in salmon trout, from half a pound to four pounds weight. About a quarter of a league from the town, the river contains a fine white earth mixed in its waters, which incrusts the earth and such plants as it touches, with a limy substance, though the water appears clear and limpid.

LETTER

L E T T E R XXII.

The source of the Tagus and its environs described.

IN going from Molina de Aragon, to the westward, you cross over mountains filled with petrifications, which appearance lasts for two or three leagues. At the third league there is a salt spring which serves the people of Molina. The ascent is continual, through a wood of fir, and over mountains, till you reach the village of Peralejos on the banks of the golden Tagus, so often sung by the poets, so frequently extolled by historians.

At Peralejos, the Tagus is only fifteen paces wide, and one foot deep. The petrifications are observed again in the village, and the river runs through a narrow channel it has made for itself, between two lofty mountains of marble, perpendicularly flitted near a hundred feet high. Each mountain is a solid block, without either horizontal, or perpendicular fissure, if we except those casual crevices, occasioned by the enormous pieces which now and then detach themselves, and roll down to the banks of the river. Such as have tumbled down on the

south

south side, have crumbled into good earth, and as the water filters through them, the soil is fertile, covered with grafs, and different plants, such as purging buckthorn, fervice, Spanish cherry, black briony, agrimony, pimpinel or common anife, and butterwort sweating drops of water. The opposite mountain is bare, without moisture, earth, plant, or mofs, being a stupendous rock resting on a bed of marble, mixed with white gypfum, veined with red, and prismatical stellated spots.

About three quarters of a league to the southward of Peralejos, you meet the highest hill in those parts called Sierra Blanca; its top is capped with calcareous rock, its body of white stone not calcareous, decomposed in the same manner as the former, with veins of imperfect jet, of the thickness of one's finger, with soft grainy pyrites (*a*) of the colour and odour of those found in the clays of Paris. Veins of bituminous wood extend from a finger to a foot in thickness, and contain pieces of jet, as large as one's head, others less, but always with vitriolic pyrites,

(*a*) Pyrites is a mineral resembling the true ores of metals in the substance of which it is composed, in its colour or lustre, in its great weight, and lastly, in the parts of the earth in which it is found, since it almost always accompanies ores. From the property of striking sparks from steel, they have been called Pyrites, which is a Greek word signifying fire-stone; they were formerly used for fire-arms as we now use flints, hence it was called carabine stone, still by some marcasite. Perhaps no other kind of natural body has had so many appellations. Persons curious to know the other names less used, may find them in Henekell's Pyritologia; we think with that celebrated chemist, that the subject has been perplexed by this multiplicity of names, for before his great and excellent work, the notions concerning Pyrites were very confused and inaccurate.—Dictionary of chemistry.

dispersed

dispersed in the very substance, and interstices of the jet. It seems clearly to be wood, as some pieces have still the bark on, exhibiting the knots, fibres, and other parts, with little alteration, still preserving their ligneous original, mixed with that, which composes the true and solid jet. What is still more extraordinary, veins of a lead mine are likewise found in it, following the oblique, or direct crevices of the wood, while other veins of lead traverse its fibres, in a perpendicular line, as well as horizontally, and some small lumps are fixed in the very substance of the wood. In a word, the four principal orders in mines, may be observed here in a small compass, as it were in miniature, viz. perpendicular veins, cross veins, strata, and masses. These veins are the more extraordinary, if we consider the manner in which the metal must have introduced itself into the timber, for it cannot be said to have made its way through the pores, when the lead was in a fluid state, because pieces of wood are found, whose exterior parts do not shew the least particle of lead, yet on breaking them, some portion of this mineral is discovered within, which could only introduce itself there, when the sap first formed the wood. The country people in the neighbourhood burn this wood, and make shot of the lead, that runs from it, which serves to kill hares, partridges, and other kinds of game, with which the country abounds. The source of the Tagus is about a league from

from the hill of Sierra Blanca, in the highest situation of Spain, for the waters of this river run down to the ocean, and those of the Guadalaviar whose source is contiguous, fall into the Mediterranean. The waters called *Vegas del Tajo*, are at a league and a half from hence, in a valley, formed by the river, which has its source in a copious spring, called *Fuente de la Abrega*. This brook, for here it deserves no better appellation, meanders so often, that it must be crossed four times in the space of half a league. Many have thought the source of the Tagus was at *Fuente Garcia*, which is five leagues higher up, but Mr. Bowles assures us to the contrary, adding, that *Fuente Garcia* is a trifling spring, which he covered with his hat, being no more, than a small quantity of water, collected in the trunk of a hollow tree, placed there to hold what issues from a puddle of standing water, which three paces further, loses itself in the adjacent valley, without a drop of it reaching the Tagus.

Half a league from *Fuente Garcia*, there is a salt spring which supplies the town of Albarracin, and eighteen villages in its jurisdiction, with salt. The country from hence to the true source of the Tagus, is an elevated plain, rather uneven, with a good carpet of grass, and a great many brambles, whose berries afford an ample repast for the black birds. It is also well stocked with that tree called in Spain *Cedro Hispanico*, the juniper thurifera
of

of Linnæus, a tall stout tree, with berries like the juniper tree of the large sort (*a*). The snow remains on the ground in these cold regions, until June, and the country is a continued chain of hills, known by the name of the *Sierra*, replete with various singularities. From Pe-ralejós hither, different petrifications are found, sometimes in the rock, and at others in the earth. If the sea deposited them there, it will be difficult to explain how this should have happened in the highest situation in Spain.

To return to the Tagus: this noble river passes by the royal palace of Aranjuez, the city of Toledo, Almaraz, and Alcantara in Estremadura; then enters Portugal, at Abrantes, and rolls its waters with dignity into the ocean at Lisbon. Philip the second opened the navigation of this river; the first boat dispatched by his majesty, arrived at Aranjuez, from Lisbon, on the 19th of January, 1582, and then returned to Toledo, to proceed down the river again (*b*); but successive events, and an alteration

(*a*) The juniper *thurifera*, or Spanish juniper, is an evergreen, little known out of Spain, though it might be of much use; it grows very high, and is similar to the juniper tree, we have in England, but the berries are larger than those of the species we have. I was informed in Spain, by a gentleman to whom I am indebted for many communications in the course of this work, that Dr. Ortega, who has visited this country, had assured him, we have it not in England; probably the climate of Spain is more favourable for its growth. Mr. Bowles calls this tree *Cedro Hispanico*, but makes it synonymous with another tree, by saying *Cedro Hispanico* o *Alerce*, whereas the *Alerce* is the *pinus larix* of Linnæus.

(*b*) Dichos y hechos de Don Philipe 2^{do}. por Balthazar Porreno. Madrid, 1748.



of dominion under Philip the fourth, put a final period to these improvements. The antient poets have been lavish in their praises of the Tagus; Silius Italicus, says,

“ Ore excellentem et spectatum fortibus ausis
Antiqua de stirpe Tagum, superumque hominumque
Immemor.”

Faria de Soufa, in his history of Portugal, relates, that king Dennis made a rich crown and scepter with the gold found in the bed of this river. Many people are still employed near Toledo, in these researches, after floods, and have collected a great number of gold coins and trinkets (*a*); though Don Antonio Ponz insinuates, that he looked in vain there for gold sand, and seems to think, that enough of it, had never been found to purchase a pair of pigeons in the market.

(*a*) Many of these curiosities had been collected by Don Francisco Palomares, of Toledo, who dying in 1775, his library and cabinet was purchased by his excellency Don Francisco Lorenzana, and presented to the public library, lately erected in that city. Another similar collection was left by Don Juan Antonio de las Infantas, dean of Toledo, to the college of St. Ildefonso, at Alcala.---Viage de Espana, por Don Antonio Ponz, segunda edicion. Madrid, 1776.

L E T T E R XXIII.

Mine of Cobalt, in the valley of Gistau, in the Pyrenees of Aragon (a).

THE valley of Gistau is almost on the summit of the Pyrenees, for very near it, at *El Hospitalet*, the waters of France and Spain divide. The river Cinca has its source here, and, passing by Plan, falls into a gully, two hundred feet broad, between two rocks, perpendicularly open, above a thousand feet high, and then passes on to the Ebro, which it enters at the lowest part of Aragon. These two rocks are like walls, where one plainly perceives the waters have forced a passage through, as the different coloured strata of stone, are similar, and exactly opposite to each other, on both sides.

(a) The kingdom of Aragon was formerly united to that of Navarre, and continued so till 1203, when Sancho the Great, who had married the heiress of the county of Castile, divided his dominions amongst his children. Garcias, the eldest, had Navarre, Ferdinand had Castile erected into a kingdom, and united to that of Leon, by marriage with Sancha, only daughter and heiress of Bermudo, last king of Leon. Gonfave had Sabrarve and other territories, and to Ramiro, his natural son, he gave the kingdom of Aragon, with the consent of the queen, in recompense for his bravery, in offering to support her innocence by single combat, against the king's sons, who had charged her with incontinency; the falsity of which accusation, was discovered by a monk, who revealed their confession to the king, on which the queen's innocence was proclaimed, and the combat laid aside, as is fully related by Roderic Archbishop of Toledo.---" Roderici Toletani de Reb. Hisp. Lib. v. chap. xxv.

The mountain of Plan is of an extraordinary height, made up of five or six hills, piled one upon another, whose divisions are in proportion to the more or less resistance of the rocks, and the quantities of earth brought down by the rains, or high winds. In the month of June I went into France, through the valley of Aure (a), exploring my way over those craggy hills which had then above five feet of snow. There are a great many bears, as well as roe-bucks, which are hunted by the people of the country, and now and then they meet with the lynx. The mutton is excellent. I bought a sheep for a dollar, (3s. 6d.) and had it dressed with *chenopodium pirenacum*, "wild spinnage" which is found in great plenty on these hills, where I shivered with cold, in the dog days, and saw a great many white partridges, but not a single fly.

There are three lead mines and one of copper, in the neighbourhood of Plan, and a good iron mine at Bielsa, which is worked with much judgment: also much lime rock, and gypsum, as white as snow, and large lumps of grey granite, dispersed in the bed of the river Cinca, where there is no sand, but stones of this kind, from the largest to the most diminutive size. One likewise finds grit stone of the same grain and colour, as that on the mountain of Elizondo in Navarre, and a great deal of millstone; the best of these are generally at the top

(a) This is Mr. Bowles's itinerary, which is preserved entire in the course of this letter.

of the mountain, being the hardest and most compact, better even than those in the centre. One should always prefer those with visible, and deep pores, and small cavities, as the heat arising from the friction, is by this means dispersed over the whole mass. This is the sort found at Gistau. Those that are smooth grained, generate too much heat, which has an effect on the flour. The soft ones are the worst of all, requiring constant repairs, and soon wear out, besides the inconvenience of rendering the bread gritty.

Having made some experiments at Plan, on some lead ore, I found in a flaty mountain, called Sahun, I discovered it to be mixed with white spar, and so abundant and easy to fuse, that it left fifty pound of lead per quintal, notwithstanding that the plane had not a sufficient declivity, for the metal to run off, as it ought to do.

The environs of Plan abound in fir, oak, and beech, of which they make charcoal for the mines; and here one finds that extraordinary mine of Cobalt (*a*), which

(*a*) Ores of cobalt resemble those of antimony; their surface is almost always covered with an efflorescence, of a dingy scarlet. These ores contain a good deal of arsenic, and it is from them that arsenic is usually got; they also frequently contain a portion of bismuth. Those which contain cobalt alone, are very rare: Cobalt mines bring in a considerable revenue to Saxony, where the ores are worked with a good deal of intelligence.-----Beaume manual of Chemistry.

☞ In the year 1755, Mr. Bowles was ordered, by the court of Spain, to attend his Excellency Don Joseph Augustine de Llano, to the manufacture of Zaffre, at Gingemback, in the Black Forest, in Germany.

has

has not its equal in Europe, except that famous one at Shoenberg, in Saxony, for whatever is found in other places is mixed in arfenical veins of lead, or silver, and in such small quantities as not to deserve any particular notice. I shall now relate the particular circumstances I was informed of, concerning this famous mine at Gistau.

At the beginning of this century, a person having observed, that some stone, found in a steep mountain, situated to the North East of that, of Plan, was more heavy than usual, it induced him to suspect, it might be silver ore, on which he repaired to Zaragossa, and shewed it to a person conversant in mines; but after various fruitless essays, no silver was found; at last they discovered it to be a mine of cobalt, and some specimens of it were sent to the manufacturers of Zaffre, in Germany, where, finding it, on trial, to be good, they determined to get possession of it, without apprising the Spaniards of its value. To carry on this scheme the better, a German was sent into Spain, to conclude this business with the simple Aragonian, and it was agreed upon, between them, that the Spaniard should petition his court for a grant of the mines of the valley of Gistau, on ceding to the king, a certain quantity of lead, yearly, at a low price; on which condition the grant was easily obtained; none suspecting that these mines contained
any

any other mineral. A private agreement was further entered into, between the German and the Spaniard, that the latter should yield to the former, all the cobalt they might get out of the mine, at the price of thirty-five *pesetas* per quintal, gross weight (a).

The people of Aragon, understanding little of mines, Germans were sent for, and they began to extract the cobalt, which they found about half way in the mountain, on whose summit there was another mine, called after Philip the IVth, perhaps from its having been attempted in his reign, though I do not know what ore it contained, but suspect it to have been cobalt; which, not being much known, at that time, nor its uses in commerce (b), was soon after abandoned, no silver appearing, which, was probably their object; but I am surprized they should have filled it up again, when they left the other mines of copper, and lead, open, which are in the very same place.

(a) A *peseta*, or pistreen, is a silver coin, worth about ten-pence sterling.

(b) This ignorance of the value of cobalt is not peculiar to the Spaniards; the same happened in Germany, where we are informed, that, for want of a sufficient knowledge of mineralogical science, quantities of rich ores, and fossile substances, have been formerly thrown away amidst the rubbish. There is scarce a mining country, in which they have not, some time or other, paved their highways with stones, and rocks of value; I know, from very reputable authority, (says a German writer) that, this was formerly the case of the cobalt ores in Hesse, which at present, produce an annual revenue of about £14000. sterling, clear of all expences. "Raspe's preface to his English translation of Baron Born's travels through the Bannat of Temeswar, Transylvania, and Hungary, in 1770. London 1777.

The Germans, for a long time, got out of this mine, about five or six hundred quintals per annum, sent it from Plan to Toulouse, where it was embarked on the canal of Languedoc, and then by Lyons and Strasburg, forwarded to their own manufactures. After they had, in a manner deflowered the mine, and got as much ore as they could easily extract, it was probably no longer an object of interest, and then they abandoned it, which happened a few years before I arrived there, in 1753.

Impatient to visit this mine, I went to it immediately on my arrival at Plan, and found many shafts in all that part of the mountain, for as cobalt does not run usually in veins, the Germans had tried different places, wherever they thought they could get it most readily. On examining these shafts, I found several pieces of good cobalt, of a finer grain, and the blueish grey colour, lighter, than that of Saxony. I cannot give an idea of it, to those who have not seen it, nor teach them, to distinguish it from other metals, of the same colour, as without ocular inspection, explanations are to very little purpose; however, I shall just add, that most of the lumps of cobalt I found here, were contiguous to a kind of hard slate, as glossy as if they were varnished, with spots, of the colour of a dried rose, without touching the cobalt, though it was as much exposed to the moisture as the slate: nor have these rose coloured spots, either grown livelier, or paler,

paler, during the many years I have had them in my cabinet. These spotted plates may serve as a direction to such as are employed in search of this mineral; for my part, I could not make any further observations with exactness, as the exclusive charter was still in force, and they watched my motions with jealousy, therefore was obliged to be satisfied with the observations I had made, without excavations, and quitted Spain about that time.

Should the Spaniards ever think seriously of Cobalt, as it exists in this mountain, and probably in other parts of the kingdom, as well as in America, I shall add the following directions for its discovery, not intending it for the use of chemists by profession, who are not in any need of it, but only for miners, who have never seen any Cobalt, or for such, who, having no judgment in ores, conclude that all matter which is weighty, and yellow, must certainly contain gold, silver, or other precious metals.

If the heavy grey stone which they find, is united with the glossy black slate abovementioned, there is no doubt, but that it is cobalt, of which that slate is the blend. If the stone is quite detached from the slate, draw lines on it with a pointed iron, and if the lines appear to be black, it is a strong indication of its being cobalt: for greater security, break the stone, and reduce it in-

to powder, put it into a thin glass phial, for the thinner it is, the less liable to break; then place it in an iron vessel, filled with sand, so that the neck of the phial may be open, and the bottom not in contact, with that, of the vessel, then put it into a common kitchen oven: all the arsenic will evaporate at the neck of the phial, and the cobalt will be purified. After this process, it still preserves its grey colour, and, mixed with sand, and the ashes of soda and barrilla, is what the Saxons call zaffre; this mixture is made, because sand and quartz, are infusible, without the assistance of barrilla, or fixed alkali; but with it, they soon vitrify, and communicate the same property to the cobalt. If this zaffre is melted with a vitreous fritt, it changes into a blue glass, called *smalt*, when in masses, and *azure*, or *enamel blue*, when reduced into a fine powder, used by painters, for that beautiful blue on porcelain, and in other manufactures (a).

In the essays made on Spanish cobalt, in Germany, it appeared to be entirely free from foreign matter, and so

(a) Mr. Bowles in a note finds fault with the Encyclopedie, and other writers on chemistry, for saying, that the cobalt and zaffre of the East, are nearly exhausted, and that we have no foundation for such an assertion, and ought rather to apply the inferiority of their modern colouring, to their craft, on finding us so easily satisfied. But the principal reason given by these writers, is, on account of the considerable quantity of zaffre and smalt now exported from Europe to China, which Mr. Bowles takes no notice of. Zaffre has been thought of such use in England, that the society for the encouragement of arts, manufactures and commerce, promised in 1755, a premium of 30l. for making the most and best zaffre, and smalt from English cobalt, not less than 5 lb. weight of zaffre, and 15 lb. of smalt to be produced before the society, with satisfactory certificates.

rich

rich, of the blue colouring earth, that it imbibed three or four times more sand or quartz, than, that of Saxony. About the year 1746, it was a great fashion, in Paris, to make sympathetic ink. I set about making of it, as well as the rest, and gave nine livres (*a*) for a pound of Spanish cobalt, with which I made my ink, which was more esteemed, than any they had seen, the green colour being much more lively, than if made with the cobalt of Saxony. The Spanish mineral has not even the grey colour of the Saxon, but is blue, like melted lead, infomuch that in several manufactures, and particularly that of Count Aranda for delf-ware, at Alcora, in Valencia; they use it without any other preparation than pulverising the stone, as it is taken out of the mine, and with this blue powder in its natural state, they paint the ware without further process (*b*).

(*a*) About seven shillings and six-pence sterling.

(*b*) Cobalt has been found in Cornwall and Scotland, and probably in other parts of Europe, of various colours and hues, mixed with different substances, which mineralists have fully described, particularly Cronsted. Wallerius enumerates six different species thereof. If well calcined cobalt be treated with inflammable matter, and fluxed like other metallic calxes, it will be reduced to a semi-metal, called by Mr. Brandt, of the Swedish academy, who first produced it, *regulus of cobalt*. This regulus, and also the calx of cobalt, amongst other singular properties, makes sympathetic ink, by being dissolved in aqua regia. This ink may be applied to the drawing of landscapes, in which the ground and trees are destitute of verdure, being first drawn with Indian ink, giving an appearance of winter; but those parts covered with this preparation, resemble the spring, on being exposed to a gentle heat, when the green leaves appear on the trees, and the grass in the fields, which idea has been executed in France by an ingenious artist on a fire-screen; and as a solution of regulus of cobalt, or of zaffre, in spirits of wine, acquires a reddish colour by application of heat, more variety may still be introduced in the landscape, and fruits and flowers suddenly brought out, by the red solution, at the same time that the leaves and verdure appeared with the green.—Dict. of chemistry.

L E T T E R XXIV.

Observations on alum, with some account of an alum mine near the town of Alcaniz, in the kingdom of Aragon.

THE method of refining alum, seems at present to be totally neglected in Spain, though they have accounts of such works having been formerly carried on, particularly near Carthagená, of which nothing remains but the name of the village, which is *Alumbre*, the Spanish word for alum; but, supposing them to have been once acquainted with this process, they have now entirely lost it; and notwithstanding they have so rich a mine of it in the kingdom of Aragon, near the town of Alcaniz, belonging to the knights of Calatrava; yet the people of the country content themselves with digging it out of the earth, and selling it to the French in its primitive state, who refine it, and then send it back to the Spaniards, to be sold to the dyers at a considerable profit.

Chemists know very well, that the vitriolic acid is dispersed in most bodies all over the world, and is extracted out of many of them for sale, particularly from sulphur. Every body knows, that, alum is a crystallizable salt, composed of vitriolic acid, united with a white argillaceous earth, which many have taken for the residuum of

of burned plants, and in support of their opinion, mention Italy, as an instance, where the most alum is found; being a country formed by volcanos, as appears from the number of its calcined stones, sulphurs, pumice, and lavas, and thus attribute the origin of alum to fire, like that of sal-ammoniac: without adopting or refuting any particular systems, I shall only add, that the alum of Alcaniz, is found in a low swampy and blackish soil.

The argillaceous earth, of which alum consists, is weakly united to the vitriolic acid, for the salt of tartar, liquid, or solid, volatile alkali, salt of soda, calcareous earth, &c. dissolved in water with alum, eject the clay from the vitriolic acid, and substitute themselves in their lieu, forming new salts, more crystalline, whiter, harder, and drier, than alum itself, but experience teaches, that they are of no use in the dye-house, as the clay only, has the power of fixing the colouring particles, and giving them that brilliancy so pleasing to the eye; for when it is mixed with any of the other above-mentioned matters, the water grows turbid, the clay precipitates, and becomes visible, the other foreign earth taking its place; for which reason, the purer the alum, and the less impregnated with other bodies, it is the more proper for the dyer, and renders the colour more glossy and lively.

The alum of Aragon has the advantage of being entirely free from any foreign matter; consequently is the best

best for every purpose, superior even to that of Rome, and only requires to be cleansed from casual impurities. Its salt is found already formed, in the earth like nitre, and other common salts, in the nitreous and calcareous earths of Spain; nothing more being necessary to refine it, than a simple lixivation, to filter, and clear it from the impurities of the earth.

This lixivium is put into boilers, and evaporated over the fire, till a thin scum appears on its surface, like a cobweb; the liquor is then run off into other vessels, where, as it cools, it crystallises into larger or small masses, the form being of no manner of consequence.

After this is performed, to save the salt still dissolved in the remaining liquor, they sprinkle this liquor over the earth, prepared for the lixivium, by which means, none of the alum is lost. Perhaps if the earth which has gone through this process, was to be heaped up, in the same manner as that, out of which they get saltpetre, it might again produce a fresh stock of alum, by some interior labour of nature, with the assistance of water, and air, for the kingdom of Aragon abounds with nitrous soil, from whence they get excellent saltpetre, as is evident by the gunpowder of Villa Feliche, the most famous in Spain. If any of these workmen would set about making experiments in this manner, with aluminous earth, should it happen to succeed, it
would

would be of great service to the people of Alcaniz, who are at present in a starving condition. I shall not enter further into the properties of alum, which have been fully described, by chemical writers, particularly Mr. Maquer, in a memoir read at the academy of sciences, in 1762, and such as are desirous to be fully informed of the nature of these works, will find in the memoirs of the French academy of sciences, for 1750, a description of the famous alum works of Solfatara, in the kingdom of Naples, by the Abbe Nollet: those of Tolfa, near Civita-vecchia, in the Roman state, have been accurately described by the Abbe Mazeas, in the fifth volume of memoirs of foreign members of the same academy. And with respect to the subject at large, Mr. Monet, in his treatise *De la alunation*, has collected every necessary information for a perfect knowledge of the subject: an object of consequence to a commercial people, and has always been attended to, by enlightened nations. England, Sweden, Flanders and Italy, are the countries where alum is principally found; to say nothing of its use in medicine, I shall only add, that it is so material an ingredient in commerce, for dying and colouring, that without its assistance, neither of these branches can be tolerably performed, it being as serviceable and necessary upon stuffs, as gum water and glutinous oil are in painting.

LETTER

LETTER XXV.

*Remarkable depository of fossil bones, seen near the village of Conclud,
in Aragon.*

THE village of Conclud is about a league distant from the city of Teruel, in the kingdom of Aragon, situated on a hill of calcareous rock, degenerated into hard earth; and though it now appears very uneven, it seems to have been formerly rock which the rains have destroyed by degrees, in proportion to its greater or less resistance. Going out of the village of Conclud, towards the North, you ascend three small hills, and then come to the *Cueva Rubia*, "The Red Cave," so called from a species of red earth, which the waters of a gully have laid open. This hill is about two hundred paces long, thirty broad, and eighty in depth. The top of the hill is of calcareous rock, more or less hard, in strata, of two or three feet breadth, full of terrestrial and aquatic shells, which appear to be calcined. In the centre of the same rocks, there are bones of oxen and horses, asses teeth, and other bones of lesser domestic animals. Many of these bones seem preserved in the same state as those found in cemeteries; others seem calcined;

calcined; some are solid; and other sorts are pulverized. The thigh and shin bones of the human race are seen with their cavities full of a crystalline matter. The horns of cattle are mixed with these, and other bones of different articulations, white, yellow, and black, confusedly jumbled together, in some places there being seven or eight shin bones of men, without the least regularity or order.

These bones are generally found in a bed of rock about three feet thick, decomposed, and almost converted into earth, with a strata of superincumbent stone, from fifteen to twenty feet thick, which serves as a cover to the hill, the bed which contains the bones, rests upon a mass of red earth, and rounded limestone conglutinated with sand not unlike pudding-stone. A similar congeries is seen at the bottom of the gully, and the adjacent hills are of plaster-stone. On the other side of the gully, and near it, there is a cave blackened by the fires of shepherds, where there are bones, in a bed of hard earth, above sixty feet high, covered with different strata of rock, corresponding exactly with those on the other side; which shews that, what may have been carried away by the waters, was exactly the same as the mass that remains. The chain of hills at this place, five leagues from Abbarracin, and eight from the source of the Tagus, produces the thorny

restharrow (*a*), two species of wormwood, two of fantoline, fouthernwood, French lavender, eryngo, sage, and thyme, and wherever they dig, bones, as well as aquatic and terrestrial shells, are found, in masses of hard rock, four feet broad, and eight long; some firmly fixed and rivetted therein, with so hard and smooth a grain, as to admit of polishing like marble. At a musket shot from the gully, there is a hill of rock, which is crumbling into earth, where an infinite number of bones and teeth is found, at two feet depth, but no further. In some places, the ossified substance is entirely decayed, nothing remaining but the impression of the bones on the stone, in the same manner as it frequently happens with shells. The finding of these bones in hard rocks, and in such different gradations or conversions into earth, of various sorts, and colours, all disposed in regular strata, indicates a decomposition and recomposition, so that the hills in reality consist only of two beds, one of limestone, divided into different strata, and the other of small rounded stone, consolidated with sand and calcareous earth. In this latter part there are no bones, nor shells, which are only to be

(*a*) *Ononis spinosa*. Linn. Thorny restharrow. Notwithstanding Linnaeus makes the thorny restharrow only a variety of the other, and, from the observations of Læssing, in the *Flora Prussica*, says it becomes thorny in the autumn; yet with us they seem to be a different species; they are seldom found together, and the corn restharrow, without thorns, hath never been observed to become thorny. The smooth sort is sometimes pickled as sampire. A decoction of the roots has been recommended in cases of stone and jaundice.---
Dr. Withering's botanical arrangement, vol. 2d, page 444.

found

found in the first division, the variety of colours being purely accidental.

It is as singular to find shells, not petrified, in these rocks, as to meet with them, petrified, or the impressions of them, near Teruel; but it is still more surprizing to find rocks almost entirely composed of aquatic and terrestrial shells, confusedly huddled together, and mixed with small bones, in a thin bed of blackish earth, beneath other beds of rock, and yet not to meet with such bones in any other part, either higher or lower, sometimes above fifty feet deep.

They tell you of an entire skeleton having been discovered, but this is much to be doubted, for though many bones are white, and well preserved, none are found that correspond, or belong to each other, in that whole range of extensive ossification. These bones must have been separated from their respective parts, by some accident difficult to be accounted for at present: according to their actual position one would imagine them to have been conveyed there, by some fluid, either water, or mud: some seem to have slid horizontally from thirty, to sixty feet, which destroys all ideas of an earthquake; others have stuck fast in a bed of mud, about two feet from the surface, which by degrees has hardened in the air, others have remained on the surface, and turned into lime-

stone; finally, many fragments of bones and shells, mixed in this mud, have dried up, and become the most considerable part of the rock.

For many leagues round, the rocks are merely superficial, having always underneath, either soft earth, gypseous, or detached stones, cemented with other matter, which accounts for the facility, with which the waters form so many gullies, and little flat hills, as are seen in different parts of this country. It is probable, however, that those beds of earth were not so soft formerly, otherwise the waters would have made greater ravages, than they actually have done; though at present the destruction is great: there being many living witnesses, who recollect the astonishing progress of some of these gullies, as well as the commencement of others, which at present are small, but may one day acquire a considerable depth (*a*).

(*a*) These rocks at Concul seem to contain bones, similar to those, found in the rock of Gibraltar, large pieces of which being examined by the best anatomists in England, no human bones were discovered, and they were supposed to be bones of sheep; many of them were filled with crystallized matter. It would be an object of no small curiosity to ascertain, if possible, what animals these bones of Concul did once belong to.

Some large bones, supposed to be of elephants, were found in 1778, upon throwing up the new road near the gate of Toledo, at Madrid, and an account of them was inserted in their gazette; they are now placed in the royal cabinet of natural history at Madrid.

See a curious account of some fossil bones discovered in the islands of Cherso, and Osero, by the abate Fortis, in his travels into Dalmatia, translated from the Italian. London, 1778, 4to.

Dr. Mesny, physician to the military hospital at Florence, has lately published a treatise on some bones found on the banks of the Arno, in Tuscany, which are thought to be the bones

Objections

Objections perhaps may be started, to what has been offered, relating to the decomposition and recomposition of matter, and some may even allege, that such bodies were always one, and the same, which is contrary to experience, and ocular demonstration. In such case, they would find themselves obliged to allow that minerals, spars, crystals, &c. do not form anew, and that there is no such event in nature, as decomposition and recomposition: A principle not to be supported by any sound arguments. We need only open our eyes, and examine those enormous oyster shells, seen on the surface of the earth, between Murcia and Mula, where the soil evidently appears, to be formed by the reduction of lime rock, into calcareous earth, these shells having fastened themselves there, when that matter was in a muddy or dissolved state, and become afterwards calcareous earth; it being evident, they were not always in the state they are in at present. Let us then suppose, this earth to have hardened in the course of time, which is not improbable, and to form rock or granite; who will deny, that a decomposition, and recomposition must have happened? It is not possible indeed to produce witnesses of the fact, because the life of man is too short, and the information received from our predecessors, too defective for that purpose; to which may be added the slow and incompre-

of an elephant, or some unknown animal. The Doctor told me, when I was at Florence in 1777, that they pretended to have found the skeleton of an elephant entire.

henfible

henfible progress of nature, imperceptible to human observation. We are therefore still very much in the dark, relating to these bones, as well as, with respect to our knowledge of fossil substances in general; having yet to ascertain, a more accurate discovery of their former natural situation, as well as the true origin of the mountains, and strata of earth in which they are found (a).

(a) "Philosophers, antient and modern, (says a late writer) have hitherto considered mountains, in general, from a point of view, too confined, or entirely different from that of mineralogy and mining; being unimproved by the light of volcanos, and by that extensive knowledge, which they might have reaped, in the deepest mines, or on the highest mountains, and from the instruction of unscientific miners, they stuck only to their libraries, and to the uppermost crust of the earth, which they had an opportunity of examining, without any great trouble to themselves, in the most pleasing countries, and in the most superficial quarries of sandstone, limestone, and slate. We are not to wonder therefore, that orology, or the science of mountains, is so little understood amongst the learned, and that the descriptions of the higher mountains of Peru, Teneriffe, Switzerland, and different parts of Europe, are generally filled with meteorological observations, botany, and other accounts, which leave their very nature, in a mineralogical, and orological respect, full as unknown, as they were before. The consequence was plain, that, general conclusions have been too rashly drawn, from a single kind of mountains, and that, the pretended systems, of the origin of mountains in general, are, for the greater part, so very romantic, and superficial."—Travels through the Bannat of Temeswar, Transylvania and Hungary, by Baron Inigo Born, translated from the German, by R. E. Raspe. London, 1777. See preface, page xxix.

END OF THE FIRST PART.

P A R T II.

L E T T E R I.

Don Guillermo Bowles's journey, by order of Government, to inspect the mine of Almaden, in La Mancha, describing his new method of extracting the quicksilver from the ore of that mine; with some account of the use made of quicksilver, by the Spaniards, in the silver mines of Mexico, and Peru.

IN the year 1752, I received orders, from the ministry, to inspect the rich quicksilver mine, at Almaden, in La Mancha. Our first stage, from Madrid, was to Getafe, and from thence to Toledo. The waters of the Tagus are very good here, and mix well with soap, though they are bad at Aranjuez, on account of their union with limy and saline particles, in that part of the river. From Toledo I proceeded to Mora, through a well cultivated valley, and from thence to Confuegra, passing forwards by the Puerto Lapiche, Daimiel, and Miguelturra, to the village of Carrascal. Hitherto the country is well cultivated, but further on, the

the plains are filled with holm trees, privet, rosemary, fouthern wood, and furze with white flowers, as far as Zarzuela, and from thence to Almaden, forty-one leagues to the westward of Madrid. Here the face of the country is totally altered, and now becomes mountainous.

The quicksilver mine of Almaden is the most curious and instructive, with respect to natural history, as well as the most antient we know of in the world. Theophrastus, who lived 300 years before Christ, speaks of the cinnabar of Spain; and Vitruvius, who lived under Augustus, mentions it likewise.

Pliny says, this mine was in the province of Bætica, as it really is, Almaden being the last village of La Mancha, and only divided by a brook, from the kingdom of Cordova. He further tells us, it was always locked up, by the governor of the province, and never opened, but by express command of the Emperor; and when the quantity wanted for Rome was taken out, was instantly shut again; but since their dominion, every thing has been so altered, and overturned, that no traces are left of their labours.

The two brothers, Mark and Christopher Fugger, of Augsburg, had a grant of this mine, and were to furnish the king, yearly, with four thousand five hundred quintals

quintals of mercury, but not being able to make good their engagements, or for some other reasons, best known to themselves, they gave it up in 1635, as well as the silver mine of Guadalcanal, which was likewise in their hands, yet these Germans made such a fortune in Spain, as to leave great riches to their heirs, who now flourish in Germany, raised to the highest dignities, being counts of the sacred Roman Empire, and possessed of considerable estates in the circle of Suabia (*a*); their opulence was so conspicuous as to become a proverbial expression in Spain, *Ser rico como un Fucar*, "To be as rich as a Fugger," a simile we find in Don Quixote. There is a street of their name in Madrid.

The church, with great part of the village of Almaden, consisting of above three hundred houses, stands upon cinnabar, and the inhabitants are chiefly supported by the profits of the mine, which lies in a hill of sandy rock, forming two inclined planes, with a craggy rock on the summit, studded with specks of cinnabar, which, no doubt were the first tokens that led to the discovery of the mine. In other parts of the hill, small beds of slate appear, with veins of iron which on the surface follow

(*a*) The family of Fugger is descended from John Fugger, a citizen of Augsburg, in 1370, father of Jacob, who, from a merchant, rose to be a councillor to the Emperor. His sons, Ulric and George, were made Barons of the sacred Roman Empire, by the Emperor Maximilian, in 1504, and their descendants were afterwards raised to the exalted dignity of Counts of the Empire. They have immense property in the circle of Suabia, are divided into several branches, and allied to the greatest houses in Germany.

the direction of the hill. Some improperly call these superficial veins, for there are such in the adjacent hills, where no cinnabar was ever suspected to exist, and all the country abounds in mines of iron; what is more, in the very mine of Almaden, pieces are sometimes found, in which the iron, quicksilver, and sulphur, are so mixed together, as not to form a different body. This destroys the common opinion, that iron amongst metals, is the only one, indissoluble by mercury, the fallacy of which I have further experienced in the quicksilver mines of Hungary, where it is certain there is a mixture of iron ore, and I have seen in the quicksilver mines of the Palatinate, a great deal of ironized mineral serve as a matrice to cinnabar.

The neighbouring hills are of a similar kind of rock to that of Almaden, and furnish the same sorts of plants, which shews that cinnabar does not exhale those poisonous vapours some have imagined, nor are they obnoxious either to vegetation or mankind. A miner may sleep in security on a stratum of cinnabar, and I have counted above forty sorts of usual plants that thrived and run to seed within the precincts of the twelve furnaces where the mineral is roasted.

The felons who work there, feel no inconvenience from it, and do nothing more than wheel about the earth
in

in barrows, yet many of them are so crafty, as to counterfeit paralytic and other complaints, to impose on the benevolent disposition of those, who visit the mine. Each man costs government eight reals per day, (about two shillings) they are better fed, than any labouring man, sell half their allowance, and enjoy good health; yet from a principle of compassion, are only made to work three hours a day, and the public think their condition so infinitely wretched, as to be little short of death.

The very judges on the bench must be of that opinion, when they affix this punishment to the most atrocious crimes, yet they are deceived (*a*), and may be assured, every labourer in Almaden does of his own free will double the work of these felons, and for half the profit.

In this mine, two veins, from two to fourteen feet broad, run the length of the hill, with branches shooting out into various directions. Every one knows that the sandstone is composed of grains of different sizes, the stone of the vein is the same as in other parts of the hill, and serves as a matrice for the cinnabar, which is more or less abundant in proportion to the fineness of the sandstone, on which account some lumps of the vein will contain to the amount of ten ounces of quicksilver in the pound, and others only three.

(*a*) Mr. Bowles follows on this occasion the opinion of Don Antonio de Ulloa, in contradiction to the experience of all ages.---See Dr. Robertson's history of America, vol. 2d, note lxxxii.

The two principal veins are attended with those upper and lower strata of rock, generally observed in all veins, to which miners have given the names of the roof, and the floor. At Almaden they are of black and rotten slate, and I have occasionally seen in them a quantity of cinnabar, and large round, or flat pyrites, yellow, and sulphurous, which, being broke with the hammer, exhibit within small particles of cinnabar. The pyrites decompose and dissolve, which occasions that vitriolic moisture which shews itself in yellow spots on the linen of those who enter the mine; and as it comes out with lemon juice, it is evident they are martial pyrites. There was one of these in the King's former cabinet, that weighed sixty pounds; I collected some of three pounds. Besides pyrites, they also find in the mine, pieces of white quartz, richly ramified with cinnabar, and light spar, sometimes even crystalline, both filled with the same matter, either lamellated or in the form of rubies. There is also slate, full of them, and the chert, or *bornstein* of the Germans (*a*), is studded with cinnabar like nail heads: even pure and native mercury is seen in the crevices of slate and sandstone (*b*).

(a) Chert. *Petr. ofilix.* *Lapis corneus.* Cronsted, sect. LXIII.

(b) Though native cinnabar has ever so lively and red a colour, it has always a mixture of argillaceous, or calcareous earth, or of sand; and these substances are frequently impregnated with an arsenical taint. Even mercury, though with so pure an appearance, may yet be loaded with a pernicious vapour; for which reason, I think that native cinnabar

From

From the best information I could get, the heirs of the Fuggers rented this mine till 1645, when the King took it into his own hands, and the German miners were dismissed. The next year the crown allotted forty-five thousand trees to support the galleries of the mine, but the workmen reaped no advantage from it, the timber having been employed without art or ingenuity. The same year Don Juan Alonzo de Bustamante established the reverberatory furnaces with alludels, the Germans having only used retorts, of which many fragments are still to be seen amongst the rubbish.

The direction of the hill of Almaden is from north east to south west, having about 120 feet elevation. I went its whole length in four and twenty minutes, and its breadth in fourteen. Like most of the hills in La Mancha, it is composed of two plains, whose summit forms a peak of craggy rock, but the upper part has not that perpendicular elevation it seems to represent, for it forms an in-

should be banished from the shops. At the foot of a steep mountain, near San Felipe, in Valencia, I made excavations, and at the depth of twenty-two feet, found a hard, white, calcareous earth, containing drops of fluid mercury. This earth, being washed, in a neighbouring fountain, left twenty-five pounds of pure mercury, which was sent to Madrid, and deposited in the royal cabinet of natural history. A little above the spot where the mercury was found, there were petrifications and gypsum. From exact researches, we know that a bed of cinereous clay, two feet below the surface, extends the length of the city of Valencia, from East to West, replete with drops of mercury, which were discovered after repeated experiments in digging of wells; particularly in the house of the Marquis of Dosaguas. Thus we found it in a white calcareous earth, with petrifications, at San Felipe, and behold it in the city of Valencia, in a cinereous clay, without them!

clined

clined angle of fourteen degrees, and all the smaller rocks of the hill have more or less the same inclination. We shall next see, that a due observation of these circumstances, constitutes a principal branch of the art of mining.

The stone on these hills, as well on the superficies, as in the centre, is of the same nature as that of Fontainebleau, and the pavement of Paris : on calcining it, and examining it minutely, when it comes out of the furnace, the grains of sand are found to be of the same shape and transparency with those on the sea shore. The enormous pieces of rock which compose the internal part of the mountain, are cut with vertical fissures, and though the rocks seem to have an erect position one over the other, the length of the hill, this is not the case, for they all incline to the south.

Two veins, more or less impregnated with cinnabar, cut the hill almost vertically, and form those strata which we have said were from two to fourteen feet broad ; these unite on the most convex part of the hill, stretching as far as one hundred feet, from which happy union arose that prodigious richness of mineral called *del Rosario*, which has given many millions of quintals of quicksilver, and was in my time the occasion of that dismal fire in the mine.

A bed

A bed of rock two or three feet broad, runs from north to south, across the hill, and cuts the two veins, so that further on, there is no appearance of cinnabar. This kind of rock being prior to the forming of the ore, stops the mineral vein, which finding it so hard, cannot penetrate that way, and is obliged to turn out of its direct course. It is from this rock to the other extremity of the mine, that I said I went in fourteen minutes. If the veins ran without interruption, and always on a straight line of the same breadth, less trouble and art would be necessary in the working of mines. Let us now speak of the method of working these of Almaden before my arrival there.

The miners had never sunk their shafts according to the inclination of the vein, but had made them perpendicular, letting themselves down by pullies in buckets, from which awkward contrivance arose all the mischiefs that followed, for in proportion as they went deeper, they often lost the vein, and were obliged to open a new shaft with the same inconveniences, and thus went on, continually encreasing their shafts and galleries with similar defects, by which they not only lost a great deal of labour and time, but were deprived of a free circulation of air underneath, as that which rushed in at one part, immediately made its escape at the other, next to it, and the people were suffocated below; the
same

same would have happened in a stone quarry, as well as in a mine : moreover, the great number of galleries, filled with quantities of decayed and rotten timber, produced obnoxious vapours, and made a hanging vault of the mine, replete with danger, from the large pieces which continually tumbled in ; to prevent these inconveniences in future, I laid before the ministry the following proposals.

That a new mine should be opened lower down, and a general shaft sunk obliquely, following the direction of the vein, and leaving a staircase at every twenty feet, to go up and down. That two galleries should be extended on the vein, one to the right, and the other to the left, continuing them in proportion as the shaft went deeper. That a space of three feet should be left on the vein, between one miner and another, in the nature of steps which the French call *travailler en banquette*. By this means a file of workmen, from twenty to a hundred, might be placed commodiously, and go as deep as they pleased without danger, because the new excavations are supported with the stone and rubbish dug out of the mine, the props which serve for this purpose being solid, and not liable to the same inconveniences as timber.

The same should be done in the second vein, and they might continue their labours at pleasure ; when they go deeper,

deeper, a gallery for a communication of air, must be made from one vein to another, by which a constant circulation is kept up through the whole, as is always practised in well regulated mines.

My plan was well received by the ministry, miners were sent for from Germany, and the whole was tolerably executed. About this time the Cinnabar mine of Guancavelica, in Peru, had begun to decay, after supplying the mines of that kingdom for above two centuries past with a prodigious quantity of quicksilver (*a*), that of Almaden only furnishing Mexico, for which purpose they generally extracted five or six thousand quintals per annum, but the ministry finding it was necessary to send more to Peru, ordered a large quantity to be provided, so that from Almaden, and Almadenejos, they extracted about eighteen thousand quintals per annum, but the greatest part came from the mine worked by the Germans.

The Fuggers were the most experienced men of their age, and their shafts and galleries were according to the strictest rules of art; but they never undertook any thing very great, perhaps only considering themselves as occasional tenants, therefore endeavoured to get as much as they could at the cheapest and easiest rate, concluding their

(a) The mine of Guancavelica was first discovered in 1563. See *Noticias Americanas. Entretenimunto physico historico por Don Ant. de Ulloa. Madrid, 1772, 4to.*

harvest would be short. They appear to have directed their views where the ore was richest, which they soon after quitted, to go upon others, for we find above six hundred galleries of theirs, propped by timber, as a temporary support, which they knew could not last.

Let us now speak of those furnaces invented by Bustamante, so perfect that no alteration has been thought necessary to be made in them to this day.

The form of the furnace is similar to that of a good lime kiln (*a*), only that the chimney is placed on the anterior wall, that the flame may spread itself equally every where. On the lower part of the furnace, they first lay a stratum of the poorest sort of stone, containing the least mineral substance, over this a better sort, with the sweepings and dross, in which they suspect there might be some mercury, to which they add water, making it into a paste, and laying it on the top. Then, a little lower down, they set fire to the furnace, with faggots of terebinthus, lentiscus, cyprus, rosemary, and other shrubs which abound in the neighbourhood. The upper part of the furnace is covered with earth, leaving eight apertures of six inches

(*a*) In the memoirs of the academy of sciences of Paris for 1719, there is a circumstantial account of these furnaces, by the celebrated Bernard Juffieu, and it will not be amiss to consult the *Dictionnaire des arts & metiers*, par Jaubert. Mr. Bowles, in his dedication to the king, says, that the mine at Almaden had been rendered useless by a conflagration till he put it in repair, which fixed him in the service of that crown, and afforded him the opportunity of visiting so many parts of the kingdom.

diameter,

diameter, where a file of eight aludels are placed, properly luted in an inclined position, and terminating at a square chamber, where the quicksilver is received. The fire penetrates the stone, and heats the sulphur, by which means the mercury dilates; and as both are so volatile, they escape together, through the aludels; but the sulphur, being more penetrating, exhales in the chamber, and even works into the aludels, and the composition with which they are luted, while the mercury, from its weight, condenses, and in its passage cools, when it falls into the tubs placed to receive it. From hence it follows, that if the furnace is good, all the quicksilver in the stone, must be found in these tubs, there being only this objection against it, that the fire is not active enough, to burn all the sulphur, rarify the mercury, or extract it out of the stone; or, that the fire, being too violent, does not allow time for the metal to condense, but hurries it, united with the sulphur, so that it escapes from the aludels. To try whether either of these inconveniencies happened, I made the following experiments, before the governor, and several other persons of rank.

I caused some pounds of stone, burned in the furnace, to be pulverized, and then mixed them with the nitre and charcoal, then fired them, covering them with a vessel, previously wetted with water, to receive the vapour. As nitre, and charcoal united, burn with extra-

ordinary violence, it is evident, that if, in this mixture, there had been the least grain of quicksilver, it would necessarily rarify and condense against the sides of the moistened vessel. In effect, we did observe some mercury there, but in so small a degree, that it was hardly perceptible with a lens, and of course of no consequence; for in every fusion of ores, some minute particles will escape in the scoria.

To discover if any grains of mercury were lost in the air, I placed four large copper vessels, not tinned, in four different places, one on the eight inches of earth, which covered the furnace, whose aperture is about three feet and a half diameter, others on the first aludels, which are the hottest, another at the obtuse angle of the same, where the mercury condenses, and the other at the highest part of the chimney, in the chamber, where the aludels lead to: as it is known, with what quickness mercury unites to all metals, except iron, if it exhaled at any of these places, where the copper vessels were fixed, it would have appeared on the copper, for I left them there above twelve hours, at the expiration of which, not the least particle of mercury appeared.

In the precincts of Almaden, there are twelve furnaces, called The Twelve Apostles; each can receive about

bout 200 quintals, including good and bad stone, which in three days will produce about 40 quintals of quicksilver. Three days more are required to repair the furnace, and replace every thing properly, so that four out of the twelve, are always in action, the violent heats of the summer excepted, when a suspension from labour is unavoidable.

When we reflect on the advantages of these furnaces, they must be considered as objects of the greatest utility and honour to Spain, foreigners having likewise improved from them. The Hungarians have imitated them in their mines, by which they have considerably reduced the number of workmen, employed in the old method, with retorts. Foreigners are shewn every thing without reserve (*a*), and are permitted to examine the rocks at their leisure, and even make drafts of the furnaces, and see their method of packing-up the quicksilver in goat-skins, which is certainly the best policy, to facilitate the

(*a*) Mr. Ferber, in his travels through Italy, speaking of the quicksilver mines of Idria, in Friul, belonging to the house of Austria, says, "They consider here their common melting and ustulation of the mercurial ores, as an arcanum, and accordingly do not allow any stranger to examine their sublimation house, though even its exterior form undoubtedly, and at first sight, proves their method being the very same as that which is used at Almaden, in Spain, and has been very minutely described by Mr. Jussieu, in the memoirs of the French academy; this method is far from being perfect, and above any improvements, but probably they do not think so, else there could be no possible reason for this mystery in so common a manipulation: nothing is more opposite to the progress of science, and even to the interest of states, than so singular a reserve." Travels through Italy in 1771 and 1772, by John James Ferber. London, 1776.

operations of a mineral that, perhaps, one day or other we may be in want of ourselves.

Let us enquire into the five or six thousand quintals of quicksilver, sent yearly from this place to the Mexican mines; though my account should not be entirely exact, it will come as near as is necessary in points of this nature. Many of the mines of New Spain are worked by fusion, but where fuel is scarce, or the ore very poor, they amalgamate it with quicksilver; it must be allowed the Spaniards were the first who undertook this process in 1566; it is true, it was in use in the gold mines of Hungary, but this had no connexion with the works of the Spaniards, because in Hungary, the ore either appears to the naked eye, or is perceived with a lens, and as every body knows that quicksilver mingles with gold, it was natural to suppose, it could be extracted by this method; but none before the Spaniards ever thought of mixing quicksilver with a stone, containing invisible silver, dissolved with sulphur, and arsenic, and oftentimes mixed with copper, lead, and iron. They therefore discovered an ingenious mode of reducing a poor ore to an impalpable powder, and to form a mass of about twenty-five quintals, mixing it afterwards with salt, or green copperas, and with lime, or ashes, reduced to a fine powder.

These

These bodies, however, being of a different nature, would remain in perpetual rest, without a dissolvent to put them in action, for which purpose, they are sufficiently sprinkled with water, throwing in thirty quintals of mercury, at different times, taking care to stir it about constantly, for the space of two months. The fixed alkali of the ashes, and lime, dissolved by this means, works in the acid of the salts and copperas, which intestine action causes a violent effervescence and heat, by which means the sulphur, and arsenic, absolutely dissolve, and destroy the copper, lead, and iron. Then the imperceptible atoms of silver, escape from their confinement, are collected by the quicksilver, which amalgamates with them, and forms that substance or paste the Mexicans call *pina* (a).

By this process they collect one and a half, or two ounces of silver, from every quintal of ore, from which, according to the method practised in Europe, they would not defray workmen's wages.

(a) The most perfect silver extracted from the ore at the mines is in that form, which the Spaniards call *pinna*, which is a lump of silver extremely porous, because it is the remainder of a paste made up of silver dust and mercury, and the latter being exhaled, leaves this remainder of the mass spongy, full of holes, and light. It is this kind of silver that is put into different forms by the merchants, in order to cheat the king of his duty, &c.---See the process of the ore from this mine to this kind of cake or mass. In Voyage to Peru, performed by the ship *Conde* of St. Malo. Written by the chaplain. London, 1759.

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LETTER