







AN

ESSAY

ON

QUICK-LIME,

AS A

CEMENT

AND AS A

MANURE.

ВY

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And he gave it for his opinion, that wherver could make two ears of corn, or two blades of grafs, is grew upon a floot of ground where only one grew before, would deferve bitter of mankind, and do more effential fervice to his country, than the whole race of Politician put together.

SWIFT.

Bofton :

PRINTED BY SAMUEL ETHERIDGE, For JOSEPH NANCREDE, NO. 49, Marlboro'-Street.



AN ESSAY

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ADVERTISEMENT.

THE nature of the fubject difcuffed in the following Effay, neceffarily required that it fhould be treated in a fcientific manner. The Author has endeavoured to render it as perfpicuous as poffible; but is afraid, that, to those who may never have been verfant in fludies of this fort, it may ftill in fome places appear a little abftrufe. On this occafion, he hopes to meet with the indulgence of those who think no exertion of of mind improperly beftowed, when it is in the purfuit of uleful knowledge.— Others who do not care to engage in intricate difcuffions of any fort, he would advife to pafs over this Effay entirely; or at leaft the *firft part* of it. The *reafons* for what is advanced in the fecond part, will not indeed be in that cafe fo clearly feen; but the practical farmer, if not thoroughly *inftructed* by that, may at leaft be *directed* to what he ought to do.

AN

third, white the similar white may measure there

AN ESSAY ON QUICK-LIME.

QUICK-LIME is a calx, or a very fine powder, obtained by burning marble, chalk, or lime-flone, and afterwards throwing water upon it.

This powder, when newly burnt, is foluble* in water; — is capable of being formed into a firm cement, if properly mixed up with water, — and is poffelfed of many other peculiar qualities that it is unnecefiltry here to enumerate.

In common language, this powder is ufually difinguinded by the name of LIME fingly. But, in the language of philolophic precifion, it is called QUICK-LIME, fo long as it remains folluble in water, and capable of being ufed as a cement. After it lofes thefe properties, it is diffinguilhed by the name of EFFETE-LIME.

In either of thefe ftates, it is employed by the farmer as a manure : And as it is a manure of the molt univerfal utility that has yet been difcovered, its nature and qualities deferve to be very particularly invettigated.

The defign of this Effay, is to point out forme of the peculiarities that conflitute the excellence of this fubflance, as a manure, and as a cement : And as what may be fail of it as a manure, will be better underflood after its pacture as a cement has been explained, it will be neceffary to confider it first in that point of view. PART

* Capable of being diffolved.

To avoid difagreeable circumlocution, I fhall be obliged, in this Effay, to employ fome technical terms not commonly underflood; but fhall explain their meaning as I go along.

PART FIRST.

OF QUICK-LIME AS A CEMENT. § 1.

IF lime-flone or marble be exposed to the action of a pretty intende fire for³ a fufficient length of time, its colour is altered, and its weight confiderably diminished: but it retains its former figure and dimensions.

In this state of burnt stone, it is in many places diftinguished by the name of *lime-shells*, or *shell-lime*, or simply *shells*.

\$ 2.

If water be thrown upon the *lime_fulls*, a confiderable heat is in a fhort time generated; the burnt flones begin to crack and fall alunder, and the mafs increafes in bulk as it gradually crumbles down, or *falls*, as it is more commonly faid, into a fine powder; which is always of a white colour, whatever was the colour of the flone before calcination.*

This powder is called *flacked lime*, or fimply *lime*; and the operation that reduces it from *fhells* to this flate, is called *flacking*.

\$ 3.

If this powder is intimately mixed with as much water as reduces it to the confiftence of a thin pafte, and afterwards dried, it concretes into one coherent mafs.

* Calcination is the operation by which any folid compact body is, by means of fire, reduced from its former coherent state, to that of a dry incoherent powder, which is called a calx. mafs, which adheres to flones, or other unpolifhed bodies, very firmly; and thus it becomes a proper cement for building walls of any fort.

After this path has been once fully dried, it becomes indiffoluble in water, fo as never to be foftened by the moliture of the air; on which account, it greatly excels clay, or any other cement that can be eafily obtained.

This cement, when compoled for building walls, is called *mortar*. When intended to be applied only as a fmooth coating upon the furface of any place, without being mixed with flones, it is called in this country fimply *plafer*.

§ 4.

It has been found by experience, that the crement made of lime that had been obtained from a lime-flone which confifted of pure *calcerous*^{*} earth alone, without any proportion of fand, never attained any great degree of hardnefs but remained a foit crumbly mafs, that might be eafly broken down by any fmall force applied to it.

And, on the contrary, if the original lime-flone contained a very large proportion of fand, the cement made of it alone was a much harder, firmer, and more durable fubftance.

And as it was difcovered, that the pureft lime might be rendered a very firm cement by the addition of a due proportion of clean hard fand, the practice of mixing fand with lime, when intended for morar, came to preval very univerfally.—The oldeft lime built walls that are now to be found, clearly fhow that this practice has been adopted before thefe were built.

Calcerous is a general term denoting all thole fubfiances that confil of the matter of which line may be made, in whatver fate it may be found—whether alone—or mixed with other fubfiances, that prevent it from being reduced to powder after calcination.

But

But it fiill remains a *defideratum* to afcertain the due proportion of fand; as authors, as well as practical malons, differ very much from one another as to this particular.

They likewife differ very much in their directions about the mode of mixing the materials, and of applying the cement ;--fome modern authors efpecially, attributing amazing effects to a fmall variation in thefe particulars, while others deny that thefe circumflances have any fenible effect on the durability or firmnels of the cement.

Thefe different and contradictory opinions feem to arile from an imperfect knowledge of the nature of quick-lime, and the variations it may admit of : For, thefe variations are fo very great, as to render it impoffible to give any general rules that can pofibly apply in all cafes. It therefore behaves thofe who with to attain any confiltency of knowledge on this fubjeck, to endeavour, firft, to afcertain the circumflances that render calcareous fublicances capable of becoming a cement at all, and then to trace the feveral changes that may be produced upon it by other extraneous caufes.

This I shall endeavour briefly to do.

\$ 5.

Lime-frome and marble are nothing elfe than a calcarcous matter *chryflallized*,* and aflume different appearances, according to accidental circumflances that have occurred at the time of their original formation-*16*. The

Saline fubfances, when diffolved in water, and put into proper circumstances for that purpole, feparate from the water, and *floot* into regular figures, which affume different forms, and are more or leis transparent according to the different nature of the fait, as nitre, aium, &c. Thefe regular transparent bodies are properly called *chryfala*.—Hence every body in nature that affumes a form and appearance finilar to thefe, and is produced in the fame manner, is fail to be *chryf*tallized. 1.1. The more perfect thefe chryftals are, the harder, and more compact, will the ftone be that confifts of them.

2d. The fmaller the proportion of extraneous matter that is entangled among these chrystak, the purer and finer will the lime be that is made from the flone which confilted of them.

From a variation in one or other of thefe two particulars, arife all the varieties of calcarcous matter that can be converted into lime; which variaties may be diffinguithed from one another by the following particulars:

1/f. When the calcareous matter is *pure*, and perfectly chryltallized; when it alfumes a clear and fomewhat transparent appearance, and is found in regular *Brata*, without many fillures, it is then called *marble*.

2.2. When the calcareous matter, is pure, but the chryftallization lefs perfect, though in regular firata, it fill obtains the name of marble; but as it is more opaque, and lefs compact than the former, it is reckoned lefs valuable, and carfer.

3.4. When the calcarcous matter is fill pretty pure, but haftily concreted into an uniform mafs, without having been in a flate that permitted it to chryftallize, or to fubfide into regular flrata, it is called *chalk*; which, when reduced to a powder without calcination, is called *whing*.

4th. When the chryftals are tolerably perfect, but have had a confiderable proportion of fand entangled among them, it is no longer called matble, but *lime*flone. And this is more or lefs *pure*, or affords a richer or poorer lime, as it contains a greater or finaller proportion of caleareous matter; and is more or lefs *bard*, according to the degree of perfection of the chryftals.

Even the pureft calcareous matter, perfectly chryftallized, is called linne-flone, and not marble, when it confifts of finall pieces that have not been concreted into regular ftrata.

5th. When

 ζ th. When the calcareous matter is perfectly pure, and fhot into fmaller chryftals, of a transparent whitenefs, it is called *fparr*—and, in other circumstances, *flaladilies*.

6th. When the calcareous matter has been formed by nature as a covering for animals, it is called *fhell*; in which clafs may be included *corals* and *corallines*.

Thefe are all the fubfiances that have hitherto been employed for making lime. The other varieties of calcareous matter, (that I may bring them all under one view, and point out their effential dillinctions) are as follow :

(yh. When the calcareous matter, while in its fuid flate, has been abforbed into a bed of clayey matter, and with it concreted into an uniform, compaG, unchryfallized mafs, it has been denominated marke; which is more or lefs pure, according to the proportion of calcareous matter it contains; and more or lefs hard, according to the nature of the clay, and the proportion of fand that may have been mixed with it. And,

8th. When *fhells*, by the lapfe of time, and by long macerating in water, have loft the animal gluten that cemented them, and are crumbled down to a fine whitifh powder, they are denominated *fhell-marle*.

oth. When thells are broken into down fmall fragments, that are ftill hard and gritty, it is called *fhell-fund*.

It would be a curious difquifition to inquire how the maffes of calcarceous matter were originally formde?—How they were reduced to a flate that rendered them foluble in water, which mult have been the cafe before they could admit of being chrytiallized?—What were the circumflances which contributed to render fome of their chrytials fo much more perfect than others ? &c. &c.—But thefe difquifitions, however curious they might be, are here omitted, as not ablolutely neeffary for the elucidation of our fubjed. The explanation of the nature of the different calcarcous matters matters above given, was neceffary; as, without a knowledge of thefe, it would have been impoffible to have explained, in a fatisfactory manner, the way in which thefe fubltances are more or lefs fitted to be employed as deement, or a manure.

To avoid unneceffary repetitions, the Reader is defired to obferve, that for the future, I fhall mention all matters that can be converted into quick-line, under the name of *line-flone*, whether they be in the form of marble, chalk, or common line-flone, diffinguifhing either of thefe when it may become neceffary.

\$ 6.

Lime-flone, in the flate we find it, is always a compound fubflance.—In its pureft flate, it confifts of a calcareous earth, united with a confiderable proportion of water; for failme matters, when chryftallized, always contain water.

Lime-stone likewise contains another substance, the nature of which will be asterwards explained.

When lime-flone has been expofed for a fufficient length of time to the action of a fufficiently intenfe free, the whole of the water it contained is evaporated : So that lime-fhells are always lighter than the flone of which they are made, by the whole weight, at leaft, of the water the chryftals contained.

And as perfect chryftals always contain a much larger proportian of water than thole that are lefs perfect, it follows, that of two kinds of lime-flome of equal purity, that which is hardefl, and moft transparent, will lofe a greater proportion of its weight in calcination, than that which is fofter and more opaque.—Hence marble lofes more weight by burning than chalk.» Again.—

* Such readers, as are totally unsequainted with the circumfances that are neceflary to the formation of chry flais in general, will probably be at a loß earlip to comprehend the chain of argumentation followed here, and in forme other parts of this Eflay. The following explanation will make it nore intelligible : As

OF QUICK-LIME

Again, — As fand lofes nothing of its weight by calcination, it likewife follows, that in two kinds of lime. Rone equally firm and well chrytkallized, the *purelf*, or that which contains the greatelt proportion of calcarcous

As faline matters, properly to called, are more eafily chryftallized by art than any others, it will be beft to take our illuftrations from that clafs of bodies.

It is a property of faline bodies, that they may all be diffolved in water.

They may also be separated from that water, and obtained in a dry form; but they assume very different appearances, according to the nature of the process that is followed for separating them from that water.

If a watery folution of any fult be fuddenly eraporated by means of fire, there remains behind a white fubdiance, fometimes flightly coherent, as in pearl-afhes, &c. and fometimes it, falls into a powdery calx, as in evaporating a folution of Glauber's falls, alum, &c.

But if the water be gently evaporated by a moderate heat before it becomes a dry powder, the falt quits the water, and fhoots out into regular figures of a transparent glassify-like appearance, which have obtained the name of chrystals.

Thefe chryftals vary in figure, hardnefs, &cc. according to the nature of the falts of which they are composed.

But they all agree in one respect, that they contain a confiderable proportion of water united with the falter matter.— Some kinds of falt abforb a very large proportion of water in this way.—Chryfallized clauber's falts contain two thirds of their weight of water.—Common falt does not contain pear fuch a large proportion.

Hence it happens, that no chryftals of any kind of falt can pofficity be formed, unlefs there falts have been perfectly diffolved in water.

And the perfection and transparency of these chrystals depend entirely on their being allowed to shoot leifurely, in that degree of heat which is belt adapted to the nature of each particular kind of falt.

For it often happens, that water can be made to difolve a much larger proportion of ful, when it is hot, than when it is cold ; fo that if a folution of thefe kinds of falts is continued in a confiderable heat, it will full remain fluid, even after it has left water than would be neceffary for forming the chyftas...In which cafe, if it is taken from the fire, and allowed to cool, it fuddenly *ensertets* into a fold opaque kind of mafs between careous matter, will lofe in calcination, the greateft proportion of weight.

From thefe facts it appears, that no rule can be given for afcertaining the proportion of weight *that* lime-ftone lofes by calcination. It mult vary in all polfible degrees, according to circumflances.

\$ 7.

Line-flone, befides the ingredients abovementioned, contains a confiderable proportion of another fluid, that enters into its compofition, and greatly alters its chemical qualities, to which philofophers have given the name of *fixed air*.⁸ This's alfo difentangled from the flone, and difforefed, in the act of calcination; as has been demonstrated by the very ingenious Dx. Black, of Edinburgh, to whole molt fasisfactory Effay on this fluipert.

between a chryftal and a calx-as may eafily be experienced, by melting chrystallized Glauber's falt in a fire-fhovel, and allowing it to cool before it is entirely evaporated to drynefs. The fame circumftances contribute to the formation of calcareous matters into chryftals, and may be eafily applied by the Reader .---- Lime is the calx produced by evaporating the chryitals to drynefs ;- and it only differs from other faline calces in this refpect, that they always retain the quality of being foluble in water, and may be converted into a liquid mass, and again chrystallized whenever that is administered to them :---whereas liche lofes that quality in a fhort time ; and if it has not been diffolved, and again chryftallized, in that fhort fpace, it must ever remain unalterably in the state it chanced to be in when it loft its faline quality .- Hence it appears in all the different flages of more or lefs perfect chryftallization, from the most transparent spar, or marble, to the most opaque chalk,-from the hardness nearly of a flint, to the loofenefs of an almost incoherent powder.

 Since this Effay was written, a total change has taken place in regard to the names of chemical fubliances—but 1 do, not think it neceffary here to make any change in that refpect, the terms being here all explained as they occur, fo as to prewent ambiguity. fubject, in the Phyfical and Literary Effays, I refer the curious Reader.

When lime-flone is thus deprived of its fixed air, it acquires many of the properties of faline bodies. It is in confequence of this that it then becomes capable of being diflolved in water,—is extremely acrid,—and ads moft powerfully on many bodies upon which it has no fenible effect while in the flate of lime-flone.

On these accounts, chemist have given it the appellation of $cau\beta ic$, when in this state, in contradistinction to its ordinary flate before calcination, or after it is again united with its fixed air, when it is fail to be in its *mild* state.

Hence, then, the phrafe *mild* when applied to calcareous earth, denotes that it is *then* united with its fixed air; which may be faid equally of it before calcination, when it is called lime-flone; or after calcination, when it is denominated *effect* lime: And *cayftic* calcareousearth is a phrafe exactly fynonymous with *guick-lime*, in its frift and philofophical acceptation; that is, calcareous earth perfectly detached, in a chemical lenfe, from every other fubfiance.

\$ 8.

But although it is pollible by art to free lime-flome from its water and air, and reduce it to the flate of an unmixed acrid faline cak; —yet no art can keep it long in that flate, as it has an irrefulfible propensity to unite itfelf again to the followares.

If water is poured upon the flone immediately after calcination, which in that flate is ufually called *linefields*, it has been already faid, that it pervades every part of the flone; each particle of the lime feems greedily to feize fome portion of the water, with which it inflantly and intimately units. In the act of union, a confiderable heat is generated, and in a fhort time its whole particles are perfectly detached from one another, other, fo as to fall down in the form of a fine, white, and feemingly dry powder, notwithflanding the large quantity of water that is thus united with it.*

¹ If lime-fhells be exported to the influence of the air, without throwing water upon them, they quickly attract moliture from thence, which flowly, and without any fentible heat, flakes the lime-fhells, and reduces them to powder.

Still, however, the lime retains its caugic quality, even after its partial union with the water : But it as irrefiltibly, though more flowly, continues to abforb the air, as the water of which it had been deprived by this calcination, and without intermifion, perpetually tends towards that mild flate which feems to be natural to it.

\$ 9.

If water is poured upon flaked lime in large quantities, that water diffolves a certain portion of the faline calx, which forms the folution called *lime-twater*, that has been much praifed as a medicine by phyficians.

But the lime has hardly had time to be diffolved by the water, before the calcareous earth abforbs a proportion of its fixed air from the water lifelf, and the furrounding atmosphere; with which it forcibly unites, and immediately again becomes mild calcareous earth, or, if you will, lime-flone. And as it is not in *bin fate* foluble in water, it immediately feparates from it, and forms a thin film of chryftallized lime-flone on the orfrace of the water. In

* The quantity of water contained in dry flaked lime, is much greater than any one could polibly imagine.—By experiment, I find that pure lime perfeilly calcined, requires at leaf its own weight of water, before it can be reduced to a powder' By the heat generated in the paration, about one tenth of that water is evaporated,—io that the drieft flaked lime, if pure, coulifit of about equal parts of calcinerous earth and water.— Such as is flaked to the ordinary degree, contains a great deal more water than is here mencioned. In this way, all the line is in a thort time feparated from the line water; and it quickly lofes all thole qualities for which it was remarkable, becoming pure and fimple water, again, unlefs fome cautic line be allowed to remain at the bottom of the velfel, upon which the water may again act, after what it had formerly diffolved had left it.

\$ 10.

It is by a precefs fomewhat fimilar to the former, that calcarcous *faladities* are formed in caverns under the earth, depending from the roof in the form of very large cicles, and other grotefque figures, that afford matter of admination and afkonifhment to the curious who vifit thefe fubterraneous caverns. It is but feldom that we are able to give fuch a diftind account of the operations of nature, as in the prefent cafe.

Thefe falacities are always formed by water dropping from the roof. This water, in thefe cafes, is always flightly impregnated with cauftic calcareous matter, which it meets with in the bowels of the earth, and diffolves.—By what procefs that calcareous matter is there rendered cauffic, remains as yet to be explained, and affords a fubject well worthy the inveftigation of the curious.*

This natural line-water, when it comes to the roof of the cavern, hangs for fome time in the form of a drop, till at length fo much water is accumulated there, as, by its natural gravity, overcomes the power of cohefion, and makes it fall to the ground. But it is no fooner fallen, than it is again fucceded by another,—and another,—and fo on *ad infututam*.

While

* Chemical philosophers have now been enabled to account for this phenomenon by the folvent power of certain gales but it is unneceffary here to enter more at large into that difcuffion, as it does not affect the explanation in the text. While thefe drops remain fulpended from the roof, the calcaroous matter contained in them greedily attracts the air all around the furface of the drop; and before it falls, a fmall part of it is reduced to a mild flate, leaves the water with which it was formerly united, and adheres firmly to the roof; which in time accumulates for much folid matter as to form a fort of nipple depending directly downwards.

After this nipple is formed, each drop, as it defcends, flows from its root towards its point, fo as to be diffuded in a thin ftream over its whole furface. In this fituation, the water is fo much exposed to the action of the air in its defcent, that a part of the calcareous matter is rendered *mild*, and is left adhering to the former, fo as to increase its diameter towards the root ; while a part flows forward to the point, and adds to its flrength, in the fame manner as it first began to be formed.

In this manner these tangleses continue to increase in fize to long as they are fuffered to remain,--and as ought to be expected from the above induction, there is always a fmall hole through the heart of each of them.

The tangles under bridges, and other artificial arches through which water is permitted to percolate, are found exaCly in the fame manner, though ufually they are lefs perfectly chryftallized.

All forts of calcareous spars owe their origin to a fimilar caufe.

While

*It is doubtful, if tangles, in the fenfe here uled, is a proper Englith word; but sati is common in Scotland, and as I know no fingle Englith word that is equivalent to it, I have ventured to adopt it. It denotes any kind of pendent concretion, refembling the thape of an icicle, of whatever kind it is formed. Any perfor who reflects on this fubject, will feel what a want it would be in the language, if the word icide were abolished : the want would hardly be lefs perceptible, if I were debarred the ule of this term.

While these natural *falatilites* are of a fmall fize, they will continue to be regularly formed, and retain the figure of ficicles; because the water, as it oozes out, will be fufficient to furround the whole of the nipple, and augment it equally on every fide. But, in time, these will become fo large, as to cause the water to flow down only on one fide, after which the figure will become difforted and irregular. Two or more will fometimes unite into one; and, in the courds of ages, an infinite diverify of fantafic forms will gradually be produced which may exhibit, on many occafions, figures of flupendous magnificence.

§ II.

The operations of nature are 6 fimple, that when we once get a glimple of the manner in which they are effected in one inflance, it is ealy to extend our obfervations, in a futisfactory manner, to others of a fimilar nature. When we once perceive the manner in which calcareous *faladilies* are formed, it is eafy to comprehend the way in which more regular firata of calcareous fubflances have been produced. The fame cavern that produces the one, will always afford examples of the other.

The drop of lime-water that falls from the roof of the cavern, although it has loft fome of the calcareous matter with which it was impregnated, fill retains a part. When it reaches the ground, it either remains fagnant, fo as to form a poole, or flows over a fmooth furface. In either of thefe cafes, it will be allowed time to abforb fome more of its air; and a part, or the whole, of the calcareous earth will be rendered *mild*, and remain in a firm chryftallized folid cake of marble.

It the fiream is confiderable, the fiber of calcarcons matter may be extended to a great diffance, thinly foread over a large declivity, as the water flows in its courfe, till at laft the whole cavity may be filled with a regular firation of lime. Gno or marble. In In this manner, within the memory of man, have huge rocks of mable been formed near Matlock, in Derbyflite, which furnifn matter of alkonithment to thofe numerous travellers who flock to fee this uncommon phenomenon. It is feldom that nature's operations are for rapid as in this inflance. But there is no room to doubt, that all the first of of alkonithment ter in the world, have been formed by a process exactly fimilar to this.

When the drops are finalter, fo as not to be fuffcient to form a large fiream, but full to flow over a finall part of the furface, irregular fwelling cakes of lime flone are produced.—When finalter fill, they rife up into high prominences, with roundith heads, fometimes refembling collyflower, and fometimes broccoli-heads.

If a current of air haftly promotes the evaporation of the water, the chryftallization will be lefs perfect. But enough has already been faid to illuftrate the fubject I have undertaken.

I now return from the operations of Nature, to those of Art.

\$ 12.

If flaked lime be exposed to the air for any length of time, in the form of a dry powder, it abforbs the fixed air allo in this flate, in a thort time lofes all its qualities as a quick-lime, and, chemically confidered, differs in no refpect from the flone of which it was compoled.

If no more water has been added at flaking than was barely fufficient to make it *fall*, and if it be kept dry ever afterwards, or mixed with any dry powder, it does not harden as it abforbs its air, but remains in a powdery flate, to all appearance in no refped differing from *quick-line*.

 tion as it abforbs its air, and becomes *mild*, it concretes into a coherent mafs; firlf, upon the furface, which quickly becomes covered with a hard cruft, greatly retembling the thin cruft that is formed on the furface of moift earth by a moderate froft. Mafons, ignorant of the real caufe of this phenomenon, call it *frofted* lime; although, their own experience ought to fatisfy them, that this cruit is formed as readily in furnmer as in winter.

As lime that has abforbed its air in any of thefe ways, is altogether unfit for becoming a cement, it is evident, what a great change may be produced upon the quality of any lime, by having allowed lefs or more of it to be in this fatte, before it is worked up into mortar.

\$ 13.

If a large quantity of water be added to fresh flaked quick-lime, and beat up with it into a thin patle, the water diffuses a finall proportion of the lime, which, as it gradually abforbs its air, is converted into chryftals; between the particles of which chryfilas, that part of the lime which was not diffused, and the other extraneous matters that may have been mixed with it, are entangled, to as to form a firm coherent mafs of the whole.

The pafte formed in this manner, is called *mortar*; and this heterogenous, imperfectly femi-chryftallized mafs, conflitutes the common cement ufed for building ordinary walls.

These circumstances being premised, it will not be difficult to comprehend what are the particulars that are necessary to form the most perfect cement of this fort.

Since lime becomes a cement only in confequence of a certain degree of chryftallization taking place in the whole mafs, it is fufficiently obvious, that the firmnefs and and perfection of that cement, mult depend upon the perfection of the chryfalls, and the hardnefs of the matters that are entangled among them. For, if the chryfals are ever to perfect and hard of themfelves, if they be feparated from one another by any brittle incoherent medium, it is evident, that the whole mafsnuft memain in fome degree brittle and incoherent.

\$ 15.

Water can only diffolve a very fmall proportion of lime, even when in its molt perfect faline flate*; and, as happens with all other faline matters, no more of the lime can be reduced to a chryftalline mafs, than has been actually diffolved in the water...Hence it happens, that if mortar be made of pure lime and water alone, a very fmall proportion of the lime only can be diffolved by that fmall quantity of water that is added to it: And as this fmall proportion alone, can be afterwards chryftallized, all the remaining untilfolved particles of the lime will be entangled among the few chryftals that are formed.

And as the undiffolved lime in this mafs will in time abforb its air, and be converted into mild calcarcous earth without having had a fulficiency of water to allow it to chryttallize, it muft concrete into a friable mafs, exacilly refembling chalk : It follows, that this kind of mortar, when as dry as it can be made, and in its higheft degree of perfection, will be always loft, and eafily crumbled into powder.

§ 16.

But if, initead of forming the mortar of pure lime alone, a large proportion of fand be added to it, the water

* Thereader will obferve, that I often fpeak of lime in its faline fitate. I prefume, he will eafily underfland, that, by. that phrafe, is meant lime while it remains capable of being diffored in water ---that is, as long as it remains depixed of its fixed air ---or, in other words, while in its caufile fante. water will, in this cafe, diffolve as much of the lime as in the former, and the particles of hard fand, like flicks, or threads, when making fugar-candy or other chryftals, while furrounded by the watery folution, will help to forward the chryfallization, and render it more perfect than it otherwife would have been, fo as firmly to ecment the particles of fand to one another.

And as the granules of fand are perfectly hard of themfelves, fo as not to admit of being broken down like the particles of chalk, it necellarily follows, that the cement made of thefe materials mult be much more perfect, in every refpect, than the former.

\$ 17.

That the reader may fee the full force of the above reafoning, it is necessary he should be informed, that when calcareous matter is reduced to a cauftic calx, it becomes, in every fenfe of the word, a perfect failne fubftance, and is in this flate as entirely foluble in water as common fall or fugar; although with this difference, that lime can be furpended by water only in a much fmaller proportion. Water can difficite one third of its weight of common falt, and keep it fufpended in a fluid flate; but it can hardly difficite one thoufandh part of guick-lime before it is faturated*.

But

* The term *faturation* is employed to denote that flate of a fluid, when it has diffolved as much of a folid body as it can poffibly fufpend in is at one time.

When any faline fubflance is put into water, it is diffolved by the water, and fufpended in it till it attains what is called the point of faturation ;--aiter which, if ever fo much falt be added, not one particle more will be diffolved,--but it will remain at the bottom in its original folid late.

Water diffolves very different proportions of different falts before it is faturated. It will diffolve its own weight of Glauber's falt, one-third of its weight of common falt, and not one-thoutandth of its weight of lime.

Hence it may very readily happen, that although any particular falt could be wholly diffolved in water, a part of the falt But although lime be as entirely foluble in water when in its cauffic flate, as any other purely faline fubflance, it is quickly abforbs its air, as to have fome part of it rendered mild, before it can be wholly diffolved on any occafion, in which flate water cannot aft upon it, is othat to obtain a total folution, that proportion of it that becomes mild, requires to be again and again calcined, after frefh folutions have been drawn from it.

As fuch a large proportion of water is necesfary to diffolve any quantity of lime, it foldom happens, even in making lime water, but that more lime is added than is fulficient to faurate the whole of the water : I which cafe, fome of it fill remains at the bottom, in a condition capable of being diffolved, if more water be added to it.

But lime, it has been already fail, differs from purely faline fubilances, in this refpect: that it cannot pofibly be long fulpended in water; for it foon abforbs its air even from that element, and is thus reduced to a mild ftate, when it immediately chryftallizes, and feparates from the water.* In

fait may remain untouched, if too much has been added. Thus, if one ounce of lime is put into ten ounces of water, that water will become faurated before it fhall have diffolved one third of the quick-lime, and the remainder will remain in a folid flate, untouched.

* Although parely failur fubfances, in every flate, continue to be folubil: mwater, yet many of them become more or lefs for, in proportion to the quantity of air that is mitted with them at the time is and *m l for ar* refemble lime in this particue + lar, that they are more early diffoled when deprived of their air, than when united with it.

Alkaline † falts, firifuly fo called, like lime, may be either in a caufic or mild flate; which appellations they in like manner obtain when they are deprived of their air, or united with it. When

† The term wikili is employed to denote a certain clafs of faline bodies, whole certain diffinguinfing characteristic is, that they may be united with acids, and with them form metrical faits, as intre; common faits &c. .

OF QUICK-LIME

In confequence of this peculiarity, it neceffarily happens, that in proportion as thefe chryfals feparate from line-water, a part of it becomes pure water again, and is inflantly capable of diffolving as much cauffic

When their faits are in a *cardite* flate, they are follable in water in any proportion. They have even fuch a tendency to unite with it when in this flate, that it is extremely difficult, if on a largether impossible, to free them from the water till they are reduced to a mild flate. No art has ever yet been diffeovered, by which a carditic volatite alkali could be exhibited in a folid form, i and although dry concretions of the fixe dalkali are fouredimed by which carditic volatite alkali could be exhibited in a folid form, i and although dry concretions of the fixe dalkali are fouredimed while it is pofielfed of a certained greee of *carditisty*, yet thefe concretions are only obtained in one can they be kept in that flate without the utmost care.

Ordinary pot-shi is an alkaline fait, obtained from the affice of burnt vegetables. This is, in form enafure deprived of its air in burning the plant; but during the procefs, before the watery folution is thoroughly evaporated to drynefs, the alkali has abforbed fome part of its air, and is in iome meafture rendered mild, fo as to admit of being reduced to a dry flate by the force of fire. But as the fait is not in this flate *fartfolly* mild, the cautic part of the alkali attracts the moliture from the air with fo much power as foon to obtain enough to reduce the whole to a watery foliation, if it is not preferved from damp air with the turofic tare.

This, and every other faline fubflance, which attracts moifture from the air, and diffolves in it, is called a *delique/cent* falt.

But if this alkali be exposed to the air for a fufficient length of time, till it has flowly abforbed its whole proportion of fixed air, and with it has become one chemical mixt, forming a *perfetly* mild alkali, it is then capable of being diffolved in water, only in one certain proportion, like other falts; and may be made to fhoot unto regular clarityfals, which may be kept in a folid dry flate, when the atmosphere is in a due temperature of heat, in the fame manner as any other falt.

In this cafe, the alkali, it is plain, leaves the watera sfoonsa it has united with its air, in the finme manner as line feparates from water, and affumes a dry chrydulline form. The alkali may, indeed, be again difilowed, by adding a larger proportion of water, which the other cannot ; but, in the first particular, the parallel is alke.

Common

cauftic lime as it had loft by the former chryftallization; fo that it immediately acts upon, and diffolves another portion of the quick-lime that remained below after the water was faturated. This portion of lime is alfo chryftallized in its turn, and a treth folution takes place; and fo on, it continues conftantly chryftallizing

Common falt is, in like manuer, in part decompode* by the violent heat that takes place in our ordinary way of boiling it. A part of its acid is diffipated; the alkali that remains, is leit in its acid/it alto. Hence it has a perpetual tendency to abforb water; in confequence of which, the whole becomes a deliquefent fail. If the evaporation is made flowly enough, the chryfals are more peried; and it maybe cafily kept dry in the ordinary thate of our atmofphere.— This it is reason why great failt may be more eafly kept dry than final fait.

If, however, the alkali that is mixed with the fait had not been in a cautic fate, it is well known it would not have de-Haueleds ; for the natrum of the Ancients, or the fajil alkali of the Moders, in its native mild fate, is a firm chryfalline falt, much refembling natre, from whence it originally derives its name.

Exactly finilar to thefe are the changes produced upon common fugar, by the different procefies it may be made to undergo. Sugar is a folid concrete, obtained by evaporating to dynes the buice of the fingar cane. In the ordinary procefs for obtaining that fobflance, it is deprived of fome part of its fixed air_a-mad is haffly concreted into an imperfect fort of chrythuline maß. In this flate, it is polfielfed of a certain degree of actif caulticity, and can be difflowed in water in any proportion from the flighted degree of impregnation to perfect drynef—But when it is placed in proper circumflances, and is allowed time to abforb its air_—like the other fubflances above neutonely, it can only be difficulted in vater in proportions; and therefore quits the water as it gradually unites with its air, and affumes a regular chryflalline form.

Thefe chryfalsare diflinguilhed by the name of *finger-candy*, and are well known to be more difficultly foluble in water, to be a milder and lefs actid (weet,—and to pdfefs many other qualities different from the fugar of which they were originally formed.

 Common fait is a compound fubfiance, formed by the union of a particular acid with the fofil alkali; chryftallizing and diffolving arew, as long as any cauftic lime remains in the water to be diffolved.

It is in confequence of this conflant addien of the water and air, that lime-water always continues of an equal degree of frength, folong as any caufic lime remains, in the veffel for the water to add upon, notwithflanding the large propertions of calcareous cluythals that are continually feparating from it.

\$ 18.

From the foregoing induction, it appears, that when a large quantity of fand is mixed in the mortar, that find will bear a great proportion to the whole mafs ; fo that the water that may be mixed with the mortar will be much greater in proportion to the quantity of lime contained in this mortar, than if the whole had conflicted of pure calcareous matter.—And as the fand abforbs none of that water, after \hat{a}_{part} of the lime is chryftallized, and leparated from the water, that water, now pure, is left at liberty to act once more upon thofe few particles of cautic lime that may fill remain in the mo*ar, which will be diffolyed and converted into chryftals in their ture.

In this manner, it may happen, in fome circumflances, that a very large proportion of the line may become chryftallized ; fo that the mortar fhall confift almoft entirely of land enveloped in chryftalline matter, and become, in due time, as hard as itone itfelf ; whereas mortar, confifting of pure lime, without fand, can hardly ever be much harder than chalk.

\$19.

It is not, however, to be expected, that in any cafe, this dried mortar will aftume that transparent chryfalline form, or the compact firmnefs of marble, or limeftone.—In mortar, in fpite of the utmoft care that can ever be taken, a very confiderable quantity of the lime muft remain undiffolved ; which undiffolved lime, although it may be fo much feparated by the fand and chryftallized lime-flone, as not much to affed the hardnefs of the mortar, yet it muft ftill remain its white chalky-like appearance.

But, as marble and lime-flone, are always formed by thofe particles of lime that have been wholly diffolved in water, and from which, they have been gradually feparated by a more flow and more perfect mode of chryfallization, they have nothing of that opaque calxlike appearance, but allume other colours, and appear more firm, uniform, and compact ; the fand, and other matters that may be enveloped in them, being enticely furrounded with a pure chryftallized matter.

\$ 20.

To obtain the moft perfect kind of mortar, however, it is not enough that a large proportion of fand fhould be employed, and that the fand hhould be intimately mixed with the line. It is alfo of the utmoft importance, that a large proportion of water be added : For, without this, it is impofible that a large proportion of the lime can be chryftallized ; and the mortar, in that cafe, would confit only of a mixture of chalky matter and fand, which could hardly be made to unite all—would be little more coherent than fand by itfelf, and lefs fo than pure chalk. In that cafe, pure lime alone would afford rather a firmer cement than lime with fand.

\$ 21.

It is alfo of very great importance, that the water be retained as long in the mortar as pollible : For, if it be fuddenly evaporated, it will not only be prevented from acting a fecond time upon the lime, after a part of what was fird diffolved has been chryfallized, but even the few chryftals that would be formed when the water was fuddenly evaporating, would be of them fclves, felves, much more imperfect than they otherwise most certainly would have been.

Common falt, which confilts of chryftals haftily formed by a fudden evaporation of fea-water by means of fire, has the appearance of a dry whitifh calx, that may be eafily broken to pieces .— The fame falt, when flowly chryftallized by a gentle evaporation in the fhade, confifts of large cubical chryftals, as transfparent, and little forfier, than crown-glais.

Ordinary lump lugar, it has been faid, likewife confifts of another fubflance haftily concreted by a fudden evaporation of the fluid in which it was diffolved :--Sugar-candy, is the fame fubflance, flowly chryftallized by a more moderate evaporation. Every one knows, what a difference there is between the firmnefs of thefe two fubflances. As great mult be the difference between the firmnefs of that cement which has been flowly dried, and that which has been haftily hardened by the powerful additon of a warm air.

It is ownig to this circumitance, that the lime which remains all winter in a mortar-tub filled with water, is always found to be much firmer, and more coherent than the mortar that was taken from the fame tub, and ufed in any work of malonry; a lithough, in this cafe, the materials were exactly the fame. From the fame caufe, any work cemented with lime under water, if it has been allowed to remain unhurt till it has once become hard, is always much firmer than that which is above the furface of the water.

\$ 22.

To make the reader comprehend the full force of the foregoing readoning, I would compare lime-cement, or mortar, to a mais of matter confilting of a congeries of flones clofely compacted together, and unied by a flong comenoting matter, that had, while in a fluid flate, pervaded all the interlices between the Rones, and had afterwards become a folid indifiduple fubliance. If

If the cementing matter be exceedingly hard and coherent, and if the ftones bedded among it are alfo very hard and firm, the whole mais will become like a folid rock, without fiffures, that can hardly be broken to pieces by the power of man.

But although the cement fhould be equally firm, if the flone of which it confifts be of a foft and friable nature, fuppofe chalk or fand-ftone, the whole mafs will never be capable of attaining fuch a degree of firmnels as in the former cafe ; for, when any force is applied to break it in pieces, although the cement fhould keep its hold, the folid matter cemented by it would give way, and the whole would be eafily broke to

Now-in mortar, the fand that is added to it reprefents the flones of a folid matter in the composition, the particles of which are united together by the lime that had been formerly diffolved, and now chrvftallized. which becomes an exceedingly folid and indiffoluble concretion.

And as the particles of fand are of themfelves exceedingly hard, and the cement by which they are united equally fo, it is plain, that the whole concretion mult become extremely firm, fo as to require a very great force to difunite any particle of it from the whole mafs.

But if, inflead of employing fand, the only folid body that is entangled among the cementing matter should be chalk (which, as has been faid, must always be the cafe when the mortar confifts of pure time alone) or any other flightly coherent fubftance, let the cementing particles of that composition be ever fo perfect, it is impossible that the whole can ever attain a great degree of firmnefs ; as thefe chalky matters will be eafily broken afunder.

Many conjectures have been made about the nature of the lime-cement employed by the Ancients. It has been been thought they poliefied an art of making mortar, that has been long fince entirely loft; as the cement in the walls that have been built by them, appears to be, in many cafes, much firmer than that which has been made in modern times.—Yet, when the mortar of thefe old buildings is analized, it is found to confift of the fame materials, and nearly in the fame proportions, which we now employ.

It is probable, however, that their only fecret confifted in mixing the materials more perfectly than the rapidity or avarice of modern builders will permit; in employing their mortar in a much more fluid flate than we do now; and in allowing it to dry more flowly, which the immoderate thicknefs of many of their walls would naturally produce, without any preconcerted defign on their part.

Tradition has even handed down to our times the memory of the molt elicitial of thele particulars; as the lower clafs of people; in every part of the country, at this moment, invariably believe that thefe old walls were compofed of a mortar fo very thin, as to admit of its being poured, like a fluid, between the flones, after they were laid in the wall. And the appearance of thefe old walls, when taken down, feems to favour this popular tradition.

Nor have I any doubt but this may have been actualing the cafe. The flones in the outer part of the wall were probably bedded in mortar, nearly as we practife at prefent; and the heart, after being packed well with irregular flones, might have the interflices between them entirely filled up with fluid mortar, which would infinuate itdfl into every cranuy, and in time adhere as firmly as the flones themfelves, or even more fo, if the flones were of a flondy friable nature.

As thefe walls were ufually of very great thicknefs, it might often happen that the water in this mortar, by adding fuccefilively upon different particles of caudiclime, would at length be entirely abforbed by fucceffive chryftallizations, fo as to become perfectly dry, without any evaporation at all; in which cafe, a very large proportion of the original lime mult have been regularly chryftallized in a flow and tolerably perfect manner, fo as to actain a firmnels little inferior to lime-flowe or marble ifelf.

Upon thefe principles, it is eafy to account for the fuperior hardnefs of fome old cement, when compared with that of modern times, in which a practice very different is ufually followed, without having recourse to any wonderiul arcana whatever.

\$ 24.

A modern French author, Menfeur Loriot, after meditating much upon this fubjedt, imagines, le has made a perfect difcovery of the way in which the Ancients employed their quick-lime, to as to obtain fuch an extraordinary firm cement; from which difcovery, he thinks very important benefits may be derived to fociety.

According to his opinion, the ancient comfiled of lime and fand, nearly in the fame proportions as are commonly employed, for that purpole at prefent. But inflead of making it of flaked lime entirely, as we do now, he fays they employed a certain proportion of their lime *unflaked*, which they mixed with their mortar immediately before it was ufed.

This composition, he fays, forms a firm and durable cement, pollefling fo many valuable properties, that I choose to give them in words of his own panegyrift:

"In the course of the 1770,"" fays he, "Monfieur Lorist

I deferves to be noted, that about the fame period, Mr., Doffle, feretary to the Society of Agriculture and Arts, in the Strand, London, publified a receipt for making mortar, In imitation of that of the Ancients, which was in every refacil the fame with this of Monfeur Loriot.—Wikid of thefe was the original diffeoverer, let the parties themfelves determine.

† These extracts are taken from a Treatise, entitled, A Practical " Taking fome lime which had been a long time laked, out of a pit covered with boards, and a confiderable quantity of earth over them again, by which means the lime had preferved all its original frefhnefs, he made two parts of it, and plafhed and beat them both pericétly well.

" He then put one of thefe parts, without any addition, into a glazed earthen pot, and in that condition fet it to dry of itfelf in the fhade. Here, in proportion as it loft its moilture by evaporation, it cracked and fair in every direction; partet from the fides of then equally friable with the bits of lime dried up with the fun, which we ufually meet on the banks of our ime-pois.* "With

Pradical Elloy on Cement and Artificial Stone, jully fuppofed to be that of the Greekt and Romanu, lattly redifferented by Monfieur Loriot, Majler of Mechanics to hit Molf Chriftian Molfelly, &: Translated from the French Original, lately pubighted by the expression of the above Monarch. London, Caelel, 1772. — It appears to have been written no tby M. Loriot him felf, but fome of his friends, as he is always mentioned in the third perfor.

* It is imposible, in reading this Effay, not to remark the extreme ignorance or inaccuracy of the compiler of it, on many occasions. The prefent paragraph affords a proof of it. There can be no doubt, but that lime, if it has been every long j(alcd, will lofe all its qualities as a quick-line, and become pericCly effects, let it be ever of carefully covered.—He gives no other teil of the lime being fill poliefied of its cautific quality, but that it was covered.—For ought that appears, it might have been entirely effecte-line; is which cale, it is not all flarpring it is floading to be capable of being converted inside only wrife from its having been adkually in this flate: For, there is no man, who does not know, that lime which has been fome time flaked, may, on many occafions, be en-ployed.
With regard to the other part, Monfieur Loriot, just added to it one-third of its quantity of powdered quick-lime, and then had the whole well kneaded, in order to make the two kinds of lime perfectly incorporate with each other. This done, he put this mixture likewife into a glazed earthen pot, as he had done the first ; when, behold, it foon began to heat, and, in the space of a few minutes, acquired a degree of confiftence equal to the beft plafter, when prepared in the best manner. In short, it fet and confolidated as readily as metals in fusion when taken from the fire, and turned out a kind of instantaneous lapidification, having dried completely within a very fmall space of time, and that too without the leaft crack or flaw; nay, it adhered fo ftrongly to the fides of the pot, as not to be parted from them without breaking it."

As to this pafface, I thall only fay, that I repeated the above experiment feveral times, with all the accuracy I was capable of ; with this only difference, that I employed lime that had lain a confidrable time beat up with water, as is ufual, to allow it to *four*, in the common larguage of matons, inflead of lime that had been long covered up in a pit, like that which he employed.

The refult was, what any man who beftows a moderate degree of attention to the fubject, and the experience of mafons, might have expected, -- but extremely different from that of Monfieur Loriot.

The pafte made of the old flaked lime alone, dried flowly, --became in time a mafs flightly coherent, fomewhat harder than chalk, it having been very pure lime I employed, without fand or any other addition.

That which was made with the fame flaked lime, with one-third of its quantity of unflaked lime reduced to powder, kneaded through it, did indeed heat, as is ufual

ployed as a cement, which, at least, is capable of adhering together, and not falling down at once into a loose powder as it dries. D 2 utual in all cafes when the lime is flaked,—fwelled up, as is alfo ufual ;—but acquired no degree of hardnefs greater than the other, nor differed in any refpeck from it, excepting that it abforbed the water more quickly; and in a day or fo after it was kneaded up, when it became pretty dry, fome particles of lime-flone, which had not been burnt fo perfectly as the reft, and were therefore longer of flaking, began to heave up afreih, having lain ill this time unflaked.

On this account, although it muft only be confidered as an accidental misfortune that will not always happen, it was evidently a much worfe cement than the other.

Such is the fact. Nor is it easy to see a reason why any beneficial confequences should refult from the practice recommended .- It is well known, that if water be added to burnt lime-ftone in any way, the first effect is, that it heats, fwells, and falls down to a powder .- Even under the water, the effect is the fame. After that powder is formed, it may, by remaining under water, concrete into a folid mafs; but with whatever fubftances it is mixed, it must first feparate before it unites. In the name of common fenfe, then, where can be the difference in first reducing it to that powdery flate, and then beating it up with the water ; or in pouring the water that is necellary to reduce it to powder upon it, and allowing that powder to remain as it may fall, without being beat up with the materials ?-Some of the watery particles will at first be abforbed, which is evidently a lofs to the mortar ; and the lime will be far lefs intimately mixed with the other ingredients, than if it had been properly blended and beat up with them after it was in its fmalleft powdery flate ; which must tend to render the mortar still lefs perfect.

Monfieur Loriot's panegyrift, however, is at no lofs to produce reafons for thefe wonderful effects, that feem to him to be entirely fatisfactory. He thus proceeds: "The "The refult of this addition of the quick-line, furpriling as at first fight it might feem, is, notwithitanding, fo cally explained and accounted for, that it feems fomewhat firange that Monfieur Loriot should be the plainer than that the fudden fetting and confolidating of thefe two fubfiances muß necellarily arife from the quick-line's being carried, by a perfect analgamation, or admixture, into the inmost recelles of the flaked line, faturating it[eff with the moilture it there meets with, and thereby effecting that inflantaneous and abfolute deliccation", which, becane we are fo well accultomedto it, we fo little mind in the ulc of gypfes or platteri"

If I underftand this paragraph, it means neither more nor lefs than that thefe two fubftances unite, becaufe they necessfarily do unite moft perfectly. If it has any other meaning, I am dull enough not to percive it.

* Any one who has beflowed a moderate degree of attention to the operation of flaking line, as it is ufually performed, mult have obferved many initances of that fort of fudden deficcation,-but without perceiving any of the other effects her mentioned.

In flaking lime-fones, effecially when of the purefl fort, fo much water in needfary, and it is insibled followly, that the operators, knowing it will be all drunk up in due time, often to throw fo much on one place at an end and the unflaked filme below. — But if the lime on the top was regularly flaked before the lafter, is dried almolt entirely in a few minutes, —and, if not broke by the fwelling of the lime below, continues ever afterwards to retain that form eithy and more water is poured on it, till it has subtried all its air, it is pervance in fine that the hardine's, dec, and cannot be diffinguinded from it, either in appearance or by any other property.

This, however, will never be the cafe, unlefs the lime has been perfectly pure, fo as to diffolve in acids as entirely as fugar does in water. It would be tirefome to quote more paflages from this Treatife. Let it fuffice to obferve, that the author proceeds to tell, that this newly diffeovered cement dries and hardens almost under the hand of the operator, without cracks or flaws of any fort^{*}, that it neither expands nor contracts with the air; t--that it is impervious to moisfure, t--and may not only be employed for making roofs to houles that are fubjected to the continual dropping of water, § bafons, acquedut8s, canals, & c. that will inflatly contain water in any quantities, but even finer works of the pottery kind : q that it perfectly refills frofts; with a long *et cettera* of other qualities which it would be tirefome to enumerate; for an account of which I mult refer to the pamphlet itelf.

That Monfieur Loriot has not diffeovered a cement poffefing thefe peculiar qualities, it would be unbecoming in me to fay; feeing it is affirmed, that works have been erected with it that prove the facts in the cleareft manner. But that fuch effects will be invariably produced, merely by adding a certain proportion of unflaked lime in powder to mortar, as he afferts, or even by making the mortar entirely with powdered quick-lime, I may without hefitation venture to deny, not only from the reafoning above given, but from actual experiment again and again repeated by myfelf ; which is likewife in fome mealure corroborated by the experience of Mr. Dolfie.*

For

*P. 31. +P. 32. + Ibid. § P. 44. || P. 44,45,46. 9 P. 52.

Although Mr. Doffer recommends his new difcovered cement for many qualities, yeth chiffers extremely from M. Loriot in his account of the manner in which the union is effected: For, inflead of faying that 'it confolidates as readily as metals in fuigar when newly taken from the fire; he fays, 'it continues for for forme time, and only gradually hardens in the air.' See Doffe's Mem. of Agriculture, vol. 81, p. 20.

Mr. Doffie

For thefe realons, I am induced to think, that if Monfieur Loriot has really experienced thefe uncomnon effects from the mortar he has tried, it mult have been occationed by fome other unobferved peculiarity, and not merely by the circumstance to which he feems to aferibe it. Polibly it may have been impregnated with gy/am,* a failine tublance, naturally abconding in France; and as one of its principal ingredients is lime-flone, there is nothing extraordinary in its being found in the fame quarry chrystallized along with the lime-flone, nor any impofibility of its efcaping undecompofed, on fome occations, during the calcination of the lime. Or it may perhaps have been otherwise accidentally mixed with the lime in thefe experiments.

But in whatever way the gryfum may come there, if it be prefent, it is not to be doubted but effects fimilar in kind (though not in degree) to what M. Loriot deferibes, would, in fome meafure, refult from the practice he recommends : For, if gryfum be deprived of its moifture by calcination, it becomes a fine powder, greatly refembling the pureft line, which coagulates, if I may ufe that phraft, immediately upon the addition of water, and acquires at once all the firmnefs that it ever can be made to a tatain.

These properties of gyp/um have been long well enough known; but it never acquires the flony hardness that lime-cement is fometimes endowed with, although

Mr. Doffie does indeed afribe to his cement fome of the fame qualities that M. Loriotatritutes to his.—Some of thefe, however, are common to every fort of lime-mortar, when carefully made; and were it not a little forcign from our fubjects, it would be no difficult matter to flow in what manner an inexperienced performight have his judgmant milded with regard to fome of the other qualities that may be called more equivocal.—The imagination is a more powerful magician than all the wife men of Eg. pt 1

* Gypfum is an earthly falt, confiling of the vitriolic acid and calcareous earth.—It is bell known among artizans in this country, by the name of *Plafter of Paris*. though it takes the fmootheft polifh of any cement we know : on which account, it has long been employed as a plafter where fine ornaments are required.

I have beftowed more attention on this performance of M. Loriot than my own opinion of its importance would have exacted from me; and it is purely in deference to the opinion of others that I have endeavoured to account for fome of those phænomena he describes, fuppoling they have really happened. The inaccurate and unfcientific manner in which that pamphlet is written, makes it afford the philosophic reader but verv little fatisfaction; and that affectation of the marvellous which runs through the whole, and the many hyperbolic compliments paid to M. Loriot with which it abounds, are but ill calculated for giving the reader a favourable opinion of the intention of the compiler. Future experiments will bring to light those circumstances which feem to be at prefent doubtful and mysterious .- I now proceed to point out some other circumstances, that may influence the quality of lime-mortar.

\$ 25.

If lime-ftone be fufficiently calcined, it is deprived of all its moilture, and of all its fixed air. But experience fhows, that lime-ftone will fall to a powder on the effusion of water upon it, when it is much lefs perfectly calcined, and while it ftill retains almost the whole of its fixed air. And as mafons have hardly any other rule for judging whether lime-ftone be fufficiently calcined, except this fingle circumstance of its falling to a powder when water is poured upon it, we may thus eafily perceive, that the fame lime may be more or lefs fitted for making good mortar, according to a circumstance that, in a great measure, eludes the obfervation of operative malons : For, if it should happen that all the lime-fhells drawn from a kiln at one time, were just fufficiently calcined to make it fall to a powder

a powder with water, and no more, that powder would be altogether unfit for making mortar of any kind.

This is a cafe that can feldom happen.—But as there are a great many intermediate degrees between that flate and perfect calcination, it mult often happen that the flone will approach nearer to one of thefe extermes at one time, than at another, fo that mortar may be much more perfect at one time than at another; owing to a variation as to this particular.

\$ 26.

Every author who has written on the fubject of lime as a cement, has endeavoured to afcertain what is the due proportion of fand for making the moft perfect cement. But a litle attention to the fubject will flow, that all rules that could be preferibed as to this particular, muft be fo vague and uncertain, as to be of litle uft to the practical mafon. For,

Befides the variation that may arife from a more or lefs perfect degree of calcination, and which has juft now been taken notice of, it is a certain fact, that fome kinds of lime-flone are much more pure and contain a much fmaller proportion of fand, than others do.

I have examined lime-flone that was fo perfectly free from any mixture of fand whatever, as to diffolve in acids as entirely as fugar does among water : have allo tried another kind that contained eleven-twelfths of its whole weight of fland, and only one-twelfth part of lime ; and have met with other forts in all the intermediate proportions between thefe two extremes.

Now it would furely be abfurd to fay, that the pure lime would require as fmall a proportion of fand when made into mortar, as that which originally contained in itfelf a much larger proportion of fand than any writer on the fubject has ever ventured to preferibe for being put into mortar.

What

What adds to this uncertainty is, the variation that may arile from the circumflance laft mentioned, viz. the greater or lefs perfect degree of calcination that the flone may have undergone. For it ought to be remarked, that although lime-flone, when pure, requires a vary intenfe degree of heat to convert it into a wirrified* mais; yet when fand is mixed with the limeflone in certain proportions, a very moderate heat is fufficient to convert the whole mais into virtified *feorie*, or in the common language of the country, make it *run into danders*.

From this circumflance, it happens, that thofe who are pollefield of a very impure lime-flone, are obliged to be extremely cautious not to give it an over proportion of fuel, left it thould vitrify the flone calcined juft enough to make it fall with water, and no more ; fo that, in general, it may be prefumed, that a very large proportion of *fueb* lime is *neuer* fo fufficiently burnt as to be reduced to a perfectly cauthic flate, or to be capable of forming a cement.

But as there is no danger at any time of giving pure lime-flone too much fire, thole who pofiels luch a limeflone are not under the necefity of being afraid of erring on that fide: And as it is a lofs to them if the whole does not fall after it is drawn from the kiln, it is natural to think they will in general give it a full proportion of fuel. From hence it may be reafonably concluded, that, in general, a much larger proportion of this kind of flone will be perfectly calcined, than of the other fort.

At a venture, we may with fome flow of probabiity, conclude, that about one-tenth of *pure* lime-flone is not enough "alcined to admit of being made into mortar ; and that, of the moltimpure forts of limeflone,

* A vitrified fubflance is one that has been melted by heat, and affumes fomewhat of a glafs-like appearance, ftone, not above one-fourth part of the lime contained in it is fo much calcined as to be in a cauftic ftate.

Let us fee what variation this ought to produce as to the proportion of fand that might be added to the lime in the one or the other cafe : and, that the calculation may be more easily made, we shall suppose that the pooreft lime-flome that is ever burnt, contains onetenth of its whole weight of lime.

Ten parts of pure lime, before it could be reduced to the fame degree of fandinefs with the other, without confidering the variation that arifes from the burning, would require each of them nine parts of fand to be aded: . Therefore, ninety parts of fand hould be added to the ten, to riduce them to an equality with the other lime in its native flate.

But if we are likewife to take into the account the variation above fuppofed, that arifes from their different degrees of calcination, the account will fland thus:

Of the ten parts of pure lime, one is fuppofed to be not enough burnt to be capable of acting as a cement; fo that there remains nine only in a perfectly cauftic flate.

Of the ten parts of impure lime, nine are fand, and only one is lime; ---and from this one is to be deduced three-fourths as not enough calcined. Hence there remains jult one-fourth of one tenth-part (oneforiteth) of pure cautile lime.

But this fortieth part of the whole is united to thirty-nine other equal parts of fand and uncalcined limetione.

There remained nine whole tenth parts of the pure lime in a caultic flate; to each of which mult be added thirty-nine tenths, including the one-tenth of uncalcined lime;—fo that to reduce it to the fame flate with the former, there would need to be three hundred and fity parts of fund added.

It feems to be altogether inconceivable, that fuch a fmall proportion of calcareous matter could ever be-

come

come fufficient to cement firmly together fuch a prodigious mafs of other matters : Nor do I pretend to fay, that this could actually bachte cafe, as there may be fome error in the *data*. The following, however, I know to be a fa?:

The belt modern mortar I ever faw, was made of lime, that I myfelf had analyfed, and found it containcel eleven parts of fand to one of lime. To this there was added between twice and thrice its whole bulk of fand by meafure ; which may be allowed to have been at leaft three times its quantity by weight.

Now, fuppoing that every particle of that lime had been for perfectly calcined as to be in a cauftic flate, there could not be lefs than forty-feven parts of fand to one of lime. The reader may allow what he pleafes for the uncautic part of the lime, and make his calculation accordingly. But it is hardly polfible to fuppofe, that above one-hundredth part of this mafs, independent of the water, confitted of pure cauftic calcareous earth.

But, whatever was the exact proportion of canffic lime, the mortar was made of thefe materials in the proportions exprefied, and was employed for pinning the outfide joints of the flone-walls of a houfe futuated in a temperfutous climate, and expoded to every blaft. It is now about fourteen years fince it was finithed ; and I do not believe there has fallen to the ground, in all that time, one pound weight of the mortar.*

Had this mortar been employed in building a thick wall, where it would have been fuffered to dry flow enough, there feems to be little reafon to doubt but it would in time have become as firm as the flones of the wall itelf.

From these confiderations we may clearly see, that it is impossible to prefetibe any determinate proportion of

* After feven years longer trial, the mortar fill proves good and firm, and exhibits no appearance of ever falling. of fand to lime, as that muft vary according to the nature of the lime, and other incidental circumitances, which it would be tirefome to enumerate, and which would form an infinity of exceptions to any general rule.

But it would feem we might fafely infer, that the modernsin general, rather err in giving too little fand, than in giving too much.

It deferves, however, to be remarked, that the fand, when naturally in the lime-flone, is more intimately blended with the lime, than can polibly be ever effected by any mechanical operation; --fo that it would be in vain to hope to make good mortar artificially from pure lime, with fuch a fmall propertion of cautific calcareous matter as may fometimes be effected when the lime naturally contains a very large proportion of fand. But, there feems to be no doubt, that if a much larger proportion of fand were employed, and if that were more carefully blended and expeditionally worked than is common, the mortar would be much more perfect than ufual in modern times.

This I have tried experimentally, with the defired fuccefs.

\$ 27.

Another circumfance that tends greatly to vary the quality of the coment, and to make a greater or fmaller proportion of fand neceffary, is the mode of preparing lime before it is beaten up into mortar.

When lime is to be employed for making plafter, it is of great importance that every particle of the lime. Hone be flaked before it is worked up : For, as the fmoothnels of the furface is the circumflance molt withed for in plafter, it any particles of lime thould be beaten up in it, and employed in work before they had had fufficient time to *fall*, the water fill continuing to a da noon them after it was worked up, would infallibly *flake* thefe particles, which would then expand themfelves felves with great force, and produce those excresses upon the furface of the plaster, that are commonly known by the name of *blifters*.

Hence, therefore, if we hope to obtain a perfect kind of platter, that thall remain fmooth on the furface, and free of biliters, there is an abfolute neceffly to allow the lime to lie for a confiderable time macerating in water before it is worked up.

This operation is called in this country, fouring.

If the lime-flone be pure, and has been very perfectly calcined, there will be little danger but that the whole of the lime will fall at hift : But if it has been lefs perfectly burnt, there will be many particles that will require to lie a long time before they will be reduced to powder. This operation is therefore more neceffary with impure than pure lime; but it ought ou no occaion to be omitted, as there is not the fmalleft probability but *fone* blifters would appear on plafter made even of the *purefl* lime, if worked up and ufed immediately atter it has been flaked.

It is alfo a common practice to four the line when it is intended to be nefed in mertar. And although it is not fo indiffenfably neceffary in this cafe as when it is intended for plafter, yet, if properly performed, it is evident, that it muft, even here, be of ufe; a sany dry knots that may fall after the mortar is ufed, muft tend to diffunite the parts of it that had been already united, and render the cement much lefs perfect than if the whole had been properly mixed up with the materials before ufing.

But more circumspection is requisite in fouring lime for mortar, than for plaster. For,

As it is not neceffary that plafter fhould be endowed with a flony degree of hardnefs, there is no lofs fulfained by allowing a great proportion of the lime that is intended for that purpole, to abforb its air before it be ufed ; for a very finall quantity of *quick-lime* will befufficient to unite the whole into one flightly coherent mafs. Therefore,

44

Therefore, the only circumflance neceffary to be attended to in fouring lime for plafter, is, that it be allowed to macerate long enough, as there is no danger of ever erring on the oppofite extreme. It is indeed neceffary that it fhould lie a very long time on fome occations, before we can be certain that all the particles are thoroughly flaked. I have known pieces of lime-fhells lie upwards of fix months expofed to all the vicifitudes of winter-weather, and fall after that time. Such lightly burnt flones are indeed ufually f-parated in fitting the lime for plafter ; but as fome finall chips may efcape, it is always fafeft to allow it. to lie in the four a very long time.

This practice is also attended with another advantage of fome confequence .- For, if by this means a great proportion of the lime be allowed to abforb its air, and become effette, when it is beaten up for ule,. the water can have no fenfible effect upon that effettelime-it will only feparate the particles of cauftic lime more perfectly from one another. fo as to fuffer it to dry without cracks of any fort, and render the furface of the plafter much more fmooth and entire than it could have been if the whole had been employed while in its perfectly cauffic flate. By this means alfo, those chrystalline exudations, fo common on newly plastered walls, will be most effectually obviated. On all which accounts, the practice of allowing lime intended for plaster to macerate very long with water, ought never to be omitted but in cafes of neceffity.

But as lime is no fooner flaked than it begins to abforb its air, and as it continues to abforb more and more every minute from that period, till it becomes entirely *effette*, fo as to be rendered gradually lefs and lefs fit for forming a cement of any fort :—it follows, that if lime intended for *mortar* is allowed to lie long *in the four*, much of it will be converted into chalk, or unchryftallized *effette-lime*; in which condition it will neither admit of for much fand in ufing, nor ever become fuch a firm cement, as if a larger proportion of fand had been employed at firft, and worked up as quickly as possible into mortar, and used.

* This milady will be increased, if the lime-flone has not been very well burnt; therefore care ought to be taken to choose the very bell burnt lime for meriar; in which cafe, a very flort time, if it has been carefully fifted atter flaking, will be fufficient to make it fall as much as is necellary. For the object of principal importance here, is to have the cement as firm as pofible; and the burkling of a very forall particle of unflaked lime amongit it atterwards, will not produce fuch a fentible inconvenience as it would have done in platfer.

Thole, therefore, who with to obtain the hardeft and firmelt mortar, will be careful to get usell-burnt lime, and allow it to macerate with the water only a *very flort time* before it is uied. But the beft burnt lime I ever faw, would require to macerate fome days in the water, before there can be a certainty that the whole will be fufficiently faked.^{*}

\$ 28.

It is no unfatisfactory proof of the juffnefs of the foregoing reafoning, to obferve, that the practice which would necelfarily follow from it, is exactly what was tollowed by the ancients, if we can rely on the account given of this matter by *Vipriculus and Plany*.

Virtuerius, 16 far from recommending unliked lime for making platter, as Manieur Lariot would foggeft, recommends exprelly that it fhould be foured or macerated in water-for the very fame reafons as are given above; as it is only bittering.—His words are (ilb, vii, cap, 2) - ...' Tune de aloriis operious elt explicatodum. If a dutem crit refet, fi glebae calcis optime, ante nulto tempore quam opus luerit, macerabuner. Manyae cunson penitu macerate. Id recens fumitur - ... haiem latente critado culculos, puffulas emititos - ... opticatedis dibilevant, et difficant etitior in politicate."

\$ 28.

The reader, if he has followed me thus far, will eafily perceive, that although it be in vain to expect thofe wonderful effects from the prclice recommended by Monfieur Loriot, that he fo pompoully defcribes, yet it may happen, that if circumflances accidentally concur

—a certain proof that the ancients had been very accurate in obferving fa(i), as they could have no idea of the reasoning by which thefe facts might have been explained or corroborated.

⁴ Ruinarum urbis, fays he, ⁴ es maxime caufa, quod furto, calcis fine ferruntine fuo camenta componintura. In tritra quoque quo estudiros, co melior. In antiquarum (antiqua) sedium legibus invenitur, ne recentore trima uteretur refeeinpor y ido nulla quilla) teloria corum rima fadarere? Ilin. Bild. lib. xxxvi. cap. eg. In this paffage, Pliny frongly coutrafis mortar (camenta)

In this paffage, Pilny firongly contrafts motiar (camenta) with halder (witria.) The first, he fays (by implication) ought always to be composed of lime cam forwarmine fite, that guality by which it is enabled to unite detached matters into a fold body, and glue them as it were together. In other places of his work, he deforibes it as calcit quan web/mentiffime, limie in smoth axial flate, that is, perietely condition times.

This quality, he plainly hints, it gradually lofes by time, fo as to come at length to be *fire ferrumine fuo*; in which flate, as it is impossible to become a firm cement for building, he feverely reprehends those who use it as fuch.

But although he condemns the practice of using that old and inert lime for mortar, he immediately adds, that for plaster it is better than new, becaule it is not fo fubjeck to crack in the work. "Intriza quoque quo vetuilior, eo melior ideo nulla telloria eorum rime fradarere."

Montheur Loriot quotes this palinge, and contends, that calcipture forruming fao, means merely flaked line, in opposition to his favourite powdered lime-fhells.—What reafon he has to think for, the reader is left to judge.—It is to be obferred, however, that Moniteur Loriot does not confine the uie of his cement to making mortar.—Like thole medicines that cure all difeales, it is equally proper for plafter, and indeed it is as a plafter he chiefly recommends it. There can be no doubr, worver as great flrangers to the ufe of it in this finie, as the Biddernn.

concur to that end, a very perfect mortar may be obtained, by following his directions. For, if the flaked lime that fhall be employed has not had time to become, in a great measure, effette ;- if the unflaked fhells that are to be pounded have been perfectly calcined ;- if the lime-ftone has been of a fandy fort of itfelf ;- if the fand added to it has been of a proper kind, and in due proportion ; and if these materials be carefully mixed before they are applied, there can be no doubt but the mortar would be very good : So that it may fometimes happen, that those who follow the practice recommended by him, in making mortar for ordinary uses, may be lucky enough to fucceed to their wifh. But, as thefe favourable circumstances may not chance to occur in other cafes, they may be at other times very far from fucceeding.

That gentleman, with his ufual want of accuracy, takes no notice of any of these circumflances.—He only recommends that powdered quick-lime, by which he means pounded lime-thells, be mixed up with common mortar, made of old flaked lime, in certain proportions. He does not give the fmalled hint as to the flate of old flaked lime to be ufed as common mortar ; but feems to think it a matter of no moment, whether it thall have been fo long flaked, as to be perfectly d-ffatte, or the reverfe g-he does not, indeed, feem to know any thing about that peculiarity of lime diffinguifhed by that term.

But, independent of that circumflance, the pradice he recommends is much worfe in other refpects than that ufually followed in modern times, either for making platter or cement, efpecially the hell. For, in the ordinary operation of flaking, thole time-thells that are not enough burnt, have fome chance of being rejected when the lime is fifted , whereas, in this nucleon of pounding the whole promifcuoufly, thefe will be mixed with the others ; and therefore it may be expected that fome of the particles will remain unflaked

AS A CEMENT.

for a very long time, which will be in danger of difuniting, and bliftering the work long after it is put up.

\$ 29.

Authors almoft univerfally agree in afferting, that the hardeft lime-flone affords a lime that will confolidate into the firmeft cement; and hence it has been, in general concluded, that lime made of chalk, affords a much weaker cement than what is made of marble or lime-flone.

• It appears, however, from the foregoing obfervations, that if ever this be the cafe, it is only *incidentally*, and not *neceffarily* fo.

Lime male of pure chalk, differs not in the leaft from lime male of the pureft marble. Both confift of a fine impalpable powder, without any mixture of extraneous matter; and if they have been equally calcined, are polifield of the fame chemical qualities in every refpect. Indeed, nothing is more eafy, than to form artificial chalk from pure lime-flone, as I have more than once experienced, which the reader may alfo do, by following the directions in the margin,* if his curiofity prompts him to it.

And

* In flaking lime composed of *pure* lime-flone, it will be observed, that the pieces fall into powder much more flowly than when the lime-flone has contained any fand in it.

If a great quantity of water be fuecefilvely poured upon a large heap of hele pare lime-fuels, without filtring them, and If it be allowed to he fome time afterwards, it will be found, on opening the heap, that fome pieces of lume-fuels have only expanded confiderably in balk by the operation of faking, without being crumbled down to a powder. Thefe pieces, if allowed to remain in a clofe place, where they are not expord to the vicifitudes of the weather, will full treat the inform : and as they gradually abiorb heir sir, they acquire a fort of firmels of confiftence, and in time become chalk in every fenfe of the word,—having the fame degree of firmnels, of foitmels, and every other quality of chalk.

This is the most perfect refemblance of chalk that can be made : but, if any quantity of that pure lime be reduced to a very And the practice of the fouthern provinces of Britain, fufficiently confirms the juffnels of the beforetions. For, to the fouth of the Humber, on the eaft coaft, almoft all the lime they use is made of chalk 2; yet, there are many buildings in thefe counties, in which the cement is as firm as in any part of the iffand. Nor does the ordinary mode of building in thefe places, indicate any deficiency in the quality of their mortar; for many of their hoofes are coated on the outfide with a cruft of lime, fluck full of fmall pebbles, which remain in it very firmly for many years. We know well, that this is the moft trying manner of employing mortar.

There is, however, greater danger that lime made of chalk, fhould form, on fome occafions, a weak cement, than that from lime-ftone.

For, as chalk never contains any fand, its lime will always form a very fort cement, unlefs care be taken to mix a large proportion of fand with it, in beating up the mortar; which is not fo indifpenfably needfary in forming mortar from lime-flone, as it fometimes contains fo much fand as to form a pretty firm cement, without any additional fand at all.

Even if the lime-flone fhould be equally pure calcareous matter as the chalk, the lime of the first has a chance of becoming a firmer cement than that of the last

For, as it is impossible to reduce the pure lime-flone to

very thin pafte, at the time of flaking, and be hallily dried to a certain degree, it acquires a fort of confiltency for as to be capable of retaining its form. And if this be kept in a place not expoled to the vicifitudes of the weather, till it has attained its whole air, it will refemble chalk almoft as much as the former, and might be employed for every purpofe that the ckalk is used for.

The reader will pleafe to obferve, that this can only be done with lime that is *perfeilly* free of fand; tor if it has the leaft particle of fand among it, no art can give it the foftnefs of chalk. to a powdery calx, without fubjecting it to the action of a very firong fire, which, while it diffipates the water, and fully dries the chryflats, carries off the volde of its fixed air, fo that the calx is almost entirely cautic.

But chalk may be reduced to cals, by fuch a moderate heat as is fcarcely fufficient to diffipate any of its air $_{i}$ —fo, that what affumes the appearance of lime made from it, may be nothing elfe than a powdered *offitte* calcareous earth, which never can become a cement of any fort. But as there is no danger of vitrifying chalk by over-burning, this inconvenience may be entirely obviated by a careful and perfect calcination.

In thefe countries, therefore, where chalk-lime is common, care ought to be taken to choole only that kind of it for mortar, that has been calcined by a very firing fire, and to reject that which has been burnt by furze or brakes, as unfit for that purpofe.

But it is obvious, that as this defect arifes entirely from the unfkilfulnels of the operator, which may be eafily avoided, it ought not to be confidered as any objection to the quality of the lime, confidered in itfelf.

\$ 30.

It is unneceffary to extend our obfervations to, all the other kinds of line-flow that may be met with ; as thefe general obfervations on the two extremes, marble and chalk, may be eafly applied to all the intermediate kinds. It has been already faid, that the different friability of different forts of lime-flome arifges entirely from a finaller or greater degree of perfection in the chryftallization, which mult have been occarfoned by accidental circumflances that have occurred at the time the concretion was effected, and can have no influence on the quality of the lime when it is once more reduced to the flate of a can/fic calx. And as it does not yet appear that there is the fmalleff difference between the chemical qualities of any one kind of follie calcareous earth and another, suben perfelly pure, there is no reafon to fufped that there can be any difference between one kind of lime and another, as a comma, unlefs what may arife from the nature of the extraneous bodies that may be accidentally mixed with that calcareous matter in its native faste, or from its being more or lefs perfedly calcined.

But the only extraineous matter that is ever found in lime-flone is fand,* in greater or fmaller proportions. And as no lime-flone that can be calcined, contains fuch a large proportion of fand as is necellary for making a perfect cement, we may naturally conclude, that every kind of lime is equally fit for becoming a firm cement, if it be first reduced to a proper degree of caulificity, and has atterwards a due proportion of fand property mixed with it, before it be employed in work.

Different forts of lime, no doubt, vary very much from one another in the proportion of fand they naturally contain, and therefore muft require very different proportions of fand to be added to them before they can be made equally perfect as a cement. This is an economical confideration, of no fmall moment in fome cafes, as it may make one foor of lime vality *cheaper* than another on fome occafions, and therefore deferves to be attended to by every builder. Directions fhall be given in the Second Part of this Effay, by the help of which he may be enabled to difcover the exact proportion of fand contained in any fort of lime he may with to examine.

\$ 31.

In the preceding parts of this Effay, I have fpoken of fand as the only fubftance that is ever added to lime

* This expression requires fome limitation. See the Postfoript to this Effay.

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in forming cement; but as others have, on fome occafions, been employed for this purpole, it will be proper here to point out their feveral excellencies and defects.

Almost the only fubilances that I have known ufed as an addition to mortar, befides fand of various denominations, are powdered fand-flone, brick-du/f, and fea-fheils, that have been broken into fmall fragments.

And for forming plafter, where cloftnefs rather than hardnefs is required, the ufeful additions are, lime that has been flaked, and kept long in a dry place, till it has become nearly *effette*; powdered chalk or whiting, and *gpfum* in various proportions; befides hair, and other lubtances of that fort.

Others that have been fately recommended by Monf. Loriot, are, balls of any fort of earth dightly burnt and pounded ;—the rubbith of old buildings (by which I underfland the old mortar after it has been (cparated from the flores) reduced to powder, and fifted ; or almoft any other thing that can be reduced to a moderately fine powder.

From what has incidentally occurred relating to this head, the reader will be able to judge; in fome meafure, of the comparative value of thefe feveral additions. But, to render the fubje dt fill more clear, the following obfervations may be of ufe :

It is fufficiently certain, that none of thefe additions enter into the composition, fo as to affect its qualities as a chemical mixt; they only operate in a manner purely mechanical: For, whatever the nature of the addition may be, it polffels the fame qualities, when fo united, as it by itfelf, and may be feparated by mechanical means from the compound, unaltered. Therefore, we need give ourfelves no trouble about affecttaining their chemical qualities, but confider them merely as malks of matter that may be more or lefs fitted for this purpole by their peculiar form, degrees of hardnefs, &c.

It

It has been already flown, that *fand* ought to be preferred to chalky matters, chiefly on account of the hardnefs and firmnefs of the particles of which it confilts. And as the pureft fand confilts of detached chryftals, which are fo hard as fcarcely to admit of being broken into finaller parts, this kind of pure chryfalline transfarent fand is, perhaps, on this account, the moft proper addition that can poffibly be made to lime in forming meeter.

Sand-fone confils of an almoft innumerable congeries of finall particles of fand united to one another, in a flight manner, by fome kind of natural ecment. But as it is troublefome to reduce this kind of frome to its finalleft component parts, and as the particles of it, when not reduced to that ultimate degree of finenefs, may be cafily broken into finaller parts, it can never be looked upon as fuch a proper addition for a lime-cement as the pureft fand.

There are also many subflances that are called *fand*, which are nothing elfe than fragments of decomposed granite, moor-flone, fact all of which may be eafily reduced into smaller particles by moderate triture, and are liable to the fame objections as pounded fand-flone.

But almost any of thefe is preferable to brick-adg. Fine clay, when perfectly burnt in the fire, may be made to affume almost a flony hardnefs. But common brick is fo imperfectly burnt, as to admit of being reduced, without much trouble, to a fine impalpable powder; informuch, that it is often ufed, when in this flate, for focuring polithed iron or brafs, efpecially if the brick has had no fine fharp fand in its compofution.

As the rough particles of brick-duft may be fo eafily reduced to a fine powder, the mortar formed with it can in no cafe be of the moft perfect fort.

But brick-duft is ftill liable to a greater objection, when confidered as a component part of mortar.

Clay

Clay only loofes its quality of abforbing water, and in fome meafure of diffolving in it, by a very perfect degree of burning; fo that if any part of it has efcaped the violent action of the fire, that part, when mixed in mortar, will full be apt to abforb water whenever it may reach it, and lofe its firmnefs, and make the mafs of which it is a part, crumble to duft.

It is exacity in this manner that all forts of marie are liable to fall into powder when drenched in water, and expoded to the air; even although they fometimes appear, when dry, to be endowed with a flony hardnels.

On this account, brick-duft, which ufually confifts of the imperfect burnt bricks, ought to be confidered as a very dangerous mixture for mortar, and fhould never be employed but in cafes of abfolute neceflity.

But the balls of other forts of earth, flightly burned, as recommended by Monfieur Loriot, mult be, on many accounts, far lefs proper ; as many of thefe forts of earth cannot, by the action of fire, be deprived of their quality of abforbing water, and of becoming fort with it. So that he who should be foolish enough to employ thefe fubliances, may be certain that his cement will not only be incapable of attaining any confiderable degree of hardnefs at any time, but will alfo be liable to turn moit in a damp air, nor will be capable of retaining its firmnefs or cohefive quality in a expofed furtation.

² Powdered *limic-rubbilb* is liable to the fame objections with the foftedt fand-flone or brick-duft ; as the particles of which it confifts, never can be endowed with the adhefive firmnefs that is necellary for forming a perfect ecment.

Fine fhells are perhaps firmer than any other fubflance, next to pure fand, and may be employed where the other cannot be got, it this abounds. I have feen a cement that was as little affected by the weather as any other, and had flood firm in the work a great many vears. years, that had been originally formed with a fand confifting almoft entirely of the fragments of fhells. But it had not the rocky hardnefs of fome old mortar that we frequently meet with.

Roughly *pseudcred glaf*, if fuch a thing could be got, at a moderate expense, would form a most perfect fort of mortar; as it would not be liable to be affected with the weather, would be fufficiently hard, and confift of very irregular fragments.

Thus it appears, that 'of all the fubflances that can be eafily met with, *fand* forms the molt proper addition to line in making mortar; on which account, it has been jultly preferred to all others for that purpole.

Pure firm chryftallized fand is better than any other fort :-But all pure fands are not equally proper for this ufe.

§ 32. It has been already thown, that the principal advantages which refuted from the addition of fand in making lime-mortar, were, that it augmented the quantity of hard indifibuble matter,—and put it in our power to employ a larger quantity of water in proportion to the lime, and thus forwarded the chryftallization of the calcarcous matter, augmented the *quantity* of the chryftals, and rendered their quality more perfect. Thole kinds of fand, therefore, which pronote thele purpoles in the higheft degree, will be beft adapted for mixing with mortar.

But if fand confifts of irregular angular particles, a greater quantity of water will be retained in the vacuities formed between thefe angular pieces, than could have been if the whole had confilted of round fmooth globules; and therefore it is natural to think, that rough angular fand, will be more proper for this ufe than that which is fmoother.

Hence, if equally pure, fea-fand, which confifts of round globules, that have been worn perfectly fmooth

by

by the continued attrition upon one another on the fhore, (like the larger pebbles in the fame flutuation) will be worfe than any other fort.—River-fand will be better than it ;—and pit-fand, when quite free of earth, the beft of all.

\$ 33.

If the fand be hard, and the particles angular, it is perhaps of very little importance whether thefe be very finall, or of a larger fizz.—The fand in the lime that formed the extraordinary firm cement mentioned § 26, was as finall as could well be imagined.

⁷ Becaufe fea-fand is ufually fmaller than any other fort, and is acknowledged to be lefs proper for making mortar than many other kinds of fand, a prejudice has been in general adopted againli *fine* fand for this purpole. But this, there is readon to imagine, is only a vulgar prejudice, arifing from the peculiar figure of that fort of fand.

\$ 34.

There is another and better reafon for not employing fea-fand in mortar, viz. that there is always a chance that fome particles of falt may be formed among it, by the evaporation of the fea-water upon the fhore. And as common falt continues always to be a deliquefcent fublitance, it will have a perpetual tendency to attract moiflure from a humid air, and thus render the wall in which this mortar has been employed extremely damp and unwholefome.

⁴ It is from the fame caufe that any porous fort of flone, that has been taken from the fea flore, continues atall times to be wet in damp weather: For, while the flone remained on the flore, its pores would be, from time to time, filled with falt water ; upon the evaporation of which, the falt it contained would remain behind, within the pores of the flone, which would thus become endowed with the quality of attracking molifure from a damp air, fufficient to difform folve the falt, and make the watery folution ooze out through all its pores.

This is a phenomenon for which it is more eafy to account, than to preferibe an efficient cure.—Perhaps, no art can render the flone fufficiently dry, after it is once put into the wall.—To let it lie for a confiderable time in a flream of running fredh water before it was employed, might mitigate, at leaft, if not entirely obviate, the difeafe.

\$ 35.

For the fame reafon, lime that has been flaked with fea-water, is always unfit for being ufed as a mortar. For, as it is impolitble ever to extract that falt from the mortar, it continually attracts moilture from the air in damp weather, and oozes through the pores of the wall in form of drops of fweat, which again difappear when the weather becomes dry.

This is an inconvenience often felt :--But as the real caufe of it is feldom known, few perfons are at proper pains to guard againft it. Thofe who obtain their lime by water-carriage, are in a peculiar manner liable to be hurt by this circumilance, as the lime is, for the moft part, flaked at the fhip's fide, by the feawater, which is more eafly got than any other.

When lime that has been flaked in this manner is employed as a platter, it is rather worke than when ufed as a mortar, as it has lefs fand added to it, and has fewer pores in the infide, in which the drops of water might be allowed to lodge; i for that the wall becomes alternately covered with a cruft of dry powdery falt, and with damp tears running down its furface.

Too much care, therefore, cannot be taken to avoid ufing lime that has been flaked with fea-water,—as it will be impofible, or extremely difficult, ever to render thefe walls perfectly dry.

I have thus enumerated at much greater length than I originally intended, the feveral circumftances that contribute contribute to render lime-cement more or lefs perfcd., In doing this, I have had occalion to explain the nature of many of thofe calcareous matters which have been generally ufed as a manure, which will confiderably florten our labour in what remains of this Effay.

If I have reprehended, with fome degree of afperity, thofe who, either through ignorance, or a willul intention to deceive, have endeavoured, by fpecious pretexts, to millead the ignorant, I hope the candid will be rather ready to afcribe this to a defire of rectifying thofe abufes that might have been introduced by their means, than to any other motive. I have never found fault, but where it was necesflary to correct.*

I now

Before I quit this branch of our fubject, I may be allowed to remark, that although the dicoveries of Modern Philofophers have enabled as to account for fome of the phenomena relating to quick-line as a cement, that were altogether inexplicable to the Ancients, yet here, asin almost every branch of natural knowledge, we are fill far from having attained that fummit of perfections which fome may, perhaps too halfhy, be difpoid to imagine—In many repicts, we have as yet been juit able to penetrate the mylterious vell of nature & yet been juit able to penetrate the mylterious vell of nature & of which we have now only avery faint idea—The following hints will illustrate my meaning, and deferve the confideration of Chemical Philofophers;

There is little reafon to doubt, that *flint* is nothing elfe than calcareous matter combined with fome fubilance that has hitherto eluded the knowledge of Chymifts.

It is likewife highly probable, that the native chryfhalline concretion called quarks, by Naturalifis, is only another modification of the fame calcareous mater, combined with fome other fublitances that prevents the action of acids upon it, and gives it other fenfible qualities very different from calcareous fubliances in their ordinary flate.

There is even fome reafon to fufpect, that all the other varieties of *chryfialline* earths, including fand of every denomination, are other modifications of the fame calcareous matter.

Even argillaceous earths (clays) however different in appearance and natural qualities, in their ordinary flate, afford evident marks of the fame original. But I now go on to confider calcareous matters as a manure.

But in what manner it comes to be fo differently difguide in thefe feveral bodies,—what are their feveral component parts,—how they may be analyfed and recompounded, are fecrets of Nature, referved for the difforwary of future ages: Ad, dil thefe are difcovered, it is probable, we will never be able to account for the manner in which the moft perfect cement may be fometimes produced.

PART

PART SECOND.

OF QUICK-LIME AND OTHER CALCAREOUS SUBSTANCES, AS A MANURE.

I have been able to give, as I hope, a tolerably fatisfactory account of the rationale of the operation of line as account; and it is much to be withed, that I could purfue the fame method in the invetligation of this fublicance as a manure. But in this respect, I have as yet been able to diffeover no clue that could, with fafety, be truffed for leading through the intricate labyrinth that lies before us; on which account, I willingly thun the arduous undertaking.

It would be cafy for me here to amufe the reader with a critical analyfis of the feveral theories that have been invented by ingenious men, to account for the manner in which lime operates as a manure. It would be no difficult matter to demonftrate the defects of their feveral fyftems; and I might, with great facility, make an idle difplay of *epharent* (uperiority by ridiculing their feveral hypotheles. But as I could not tubflitute any thing in their flead, that would be more fatisfactory to the fenfible Reader, I choofe to wave this ungracious difcultion; and thail content myfelf with enumerating a few *facts* concerning the use of calcareous fubliances as a manure, that it much imports the prachical farmer fully to underfland.

δ1.

The first idea that occurs in reflecting on this fubject, is, that all fubflances in which calcareous matter is contained, have been fuccefsfully employed as a mapure, at different times, and in different places.

Thus-lime,-marle of all forts,-ehalk,-lime-flonegravel,- gravel,—fhelly fand, or pure fhells of every denomination, have all been employed as manures, with the greateft fuccefs.

\$ 2.

And as all thefe, excepting lime, always contain the calcareous matter in its mild flate, we are led to conclude, that they operate on the foil merely as calcareous, and not as faline fubftances.

Line, indeed, is formetimes applied to the foil in its cau/fic flate, as it comes freth from being flaked, but more commonly at fome confiderable diflance of time after it has been burnt. However, as burning is the only mode ufually employed for reducing lime-flone to powder, and thus preparing it for a manure, the opinion in general prevails, that calcination is as necellary for rendering lime capable of becoming a manure, as for making it fit to be employed as a cement.

It is, however, of importance to the practical farmer, to be informed that this is not the cafe.--Mr. Du-Hamel, was the firth, who, from an accidental experiment, was led to believe that *peudered lime-fone* was a manure equally efficacious with *lime* itfelf. He recorded the experiment as a great diffeovery.

Having had occation to drefs a marble chimneypiece, for repairing one of his country-houfes, the malon chofe a lawn near the houfe, as the moll convenient place for hewing the flone. After the operation was finithed, all the large chips were picked up and carried away, that they might not disfigure the lawn ; but the fine powder that had been grinded of by the addition of the chill, mixed fo intimately with the grafs, that it could not be gathered up.—In confequence of this very tull dreffing of powdered limeflone, the grafs afterwards grew upon that foot with much graesier lux triabce than on any other part of the law., and always continued to have a much livelier Verdure. From From hence, he, with good reafon, concluded, that powdered time-from ength to employed as a manure with fuccefs. To try if this would always be the cafe, he repeated the experiment feveral times, by caufing fome time-flone to be pounded on purpole ; and found that it never failed to promote the fertility of the fpot on which he applied it, in a very high degree.

I chofe to relate this experiment at large, for the fatisfation of thofe who may be unacquainted with the *phyfical* caufe of the difference between line and lime-chone. To fuch as are fully apprifed of this, a little reafoning might have been fufficient to afford a certain conviction, that the refult of the experiment much have been what Mr. Do-Hamel found it.

\$ 3.

Linne is no foorer flaked, than it immediately begins to abforb its air, and return to its former mild flate; or, in other words, it becomes *affeite*; in which flate it pollefles the fame chemical qualities, in every refpect, as lime-flone.

If this be foread out thinly upon the furface of the earth, it abforbs its air in a very fhort time,—A few hours, in this fluation, reforces a large proportion of its air; and, in a day or two, at moft, it becomes perfectly *effette*, as maions experience when they fweep together the fcattered particles that have lain round their heaps of lime, and attempt to ufe it in mortar by itelf, for it is then no more coherent than fand, or moiltened earth.

But it is well known, that lime produces fcarcely any

any fenfible effect as a manure at the beginning. Even the first year after it is applied to the foil, its effects are inconfiderable, in comparison of what it produces in the fecond and fucceeding years. From whence we mult conclude, that it operates upon the foil, merely as a *mild* calcareous earth; and that its calcination is of no farther utility in preparing it for manure, than as a cheap and efficacious method of reducing the lime-flone to a fine powder.

\$4.

It is of importance, that thefe facts flould be generally known; becaufe it may fometimes happen, that good lime-flone fhall, be found in places where fuel could not be obtained for burning it; in which, cafe, fuch lime-flone could be of no use to the farmer, if calcination were abfolutely neceflary. But, feeing this is not the cafe, lime-flone, even in thefe fituations, may be converted into a moft beneficial manure, if a fitneam of water can be commanded, fufficient for driving a mill, for reducing the flone to powder.

I have feen the model of a mill that had been invented for that purpole, which was constructed on the fame principles with an ordinary gun-powder mill. It had feveral large maffy ftampers, composed of huge blocks of calt-iron, that were successively lifted up and let fall by a wheel that catched their handles, and, after a proper time, flipped them again as it revolved round its axis. Thefe ftampers fell with great force upon the lime-ftone, that had been previoufly broken into. pieces of a moderate fize, and placed in a ftrong trough, formed for that purpofe. Through this trough, a fmall ftream of water was conveyed, which walhed away with it, the finall pieces of lime-ftone, as they were fucceflively reduced to powder by the ftampers. This stream of water was received into a large refervoir, in which it was allowed to ftagnate, and depofit, as a fediment, the lime-flone powder it brought along with it; the pure water flowing gently over a part of the brim, which was made lower for that purpofe.

When the refervoir was nearly full of this fine powder, the work was flopped; the water was drawn off from the refervoir, by taking out fome plugs left for that purpole, at different heights, till all that was clear had run of: the powdered flome was atterwards thrown out to the bank, and allowed to dry fufficiently for ufe.

I have heard that a mill, upon thefe principles, was creeded by the Honourable the Truflees for managing the forfcited effates in Scotland, and that a good deal of lime-flone was pounded with it. But, as it was credted in the Highlands of Scotland, where roads were bad, and where there was but little, firit for improvements in agriculture; a sthere was no public demand for the manure, a there the experiment was fufficiently tried to flow that it might be prachifed with advantage in other places, the mill was fuffired to lie unemployed.

But although this may be confidered as a moft valuable difcovery for those who may have a good limequarry fo fuueted as not to be within the reach of any kind of fuel for burning lime-flone; yet, to fuch as can obtain fuel at a moderate expense, there can be no doubt but that burning is the eafleft and moft efficacious mode of reducing lime-flone to powder that ever was invented, and therefore ought always to be adopted where neceffity does not prevent it.

\$ 5.

Reducing lime-flone to powder by calcination, is attended with this farther advantage to the farmer, that it confiderably diminifhes his expense of carriage. *Pure* lime-flone lofes about two-thirds of its weight by being being thoroughly burned ; fo that the man who is obliged to drive this manner from a great dillance, will find a very confiderable faving by driving it in the flate of *fbells*. But if it were reduced to a powder by mechanical triture, he could not be benefitted by this circumflance.

Many perfons choofe to drive lime-flone from a confiderable diffance, and burn it at home : But it is obvious they then fubject themfelves to a very heavy charge in carriage, which would be avoided by an oppolite conduct. This, therefore, ought never to be practified but where other circumflances may counterbalance this unfayourable one.

\$ 6.

But as lime-flone is often, in its native flate, mixed with fand in various proportions; and as fand lofes nothing of its weight by calcination, it muft happen, that thefe kinds of lime-flone which contain the largeft proportion of fand, will lofe leaft in calcination, and of courfe afford the weightieff lime-fhells.

Hence it is obvions, that thole who are under the neceflity of driving lime from a great diftance, ought to be particularly careful to make choice of a kind of lime-flone as free from fand as pollible, and to drive it in the flate of *fielt*; a sathey will thus obtain an equal quantity of manure, at the leaft expense of carriage that is pollible; and the lighted fhells ought, of courfe, to be always preferred.

When lime is flaked, that which contains moft fand falls moft quickly, and abforbs the fmalleft proportion of water. What is pure, requires a very large proportion of water, and is much longer before it begins to fall.

\$ 7.

Hence it happens, that those who drive fandy limethells in open carriages, must be very careful to guard against againft rain ; becaufe a heavy flower would make the whole fall, and generate fuch a heat as to be in danger of fetting the carts on free; whereas *pure* lime-fhells are in no danger of being damaged by that circumflance. I have feen a cart loaded with fuch thells, which had been expofed to a continued flower of rain, as violent as is ever known in this country, for more than three hours, and feemed hardly to be affected by it in the finalleft degree. I ought to obferve, however, that my experiments were confined to only one kind of pure line, fo that it is not from hence demonfirated, that *ail* kinds of pure lime will be poffeffed of the fame qualities.

\$ 8.

Line fhells formed from the purefi line-flone, require more than their own weight of water to flake them properly ***** whereas fome kinds of lime-thelis that contain much fand, do not require above onefourth part of that quantity.

Hence it is much worfe economy in those who have pure lime-fhells, to flake and carry them home in the flate of powdered lime, than it is in those who have only a fandy kind of lime-fhells.

It is even, on fome occafions, more advifable for thole who have very fandy line, to drive it in the flate of powdered line, than in that of *fletili*: For, as it is dangerous to give that kind of lime-flone too much heat, left it flould be vitrified, thole who burn it can never be *certain* that the whole of the flone will fail to powder when water is added, till they have actually tried.

* I have found, by experiment, that pure lime-fiells cannot be flaked with lefs than about one-fourth more than their own weight of water. When flaked in the ordinary way, the fame lime-fiells took more than double their weight of water. tried it ; nor do they think it a great lofs if fome part of it fhould be imperfectly burned, as it requires much lefs fuel on a future occation than frefh lime-fone ; and therefore they much rather choole to err on this, than on the oppofice extreme.

But, thould any one attempt to drive this peer fort of lime in the flate of *fbells*, he would be in danger of carrying home many flones that would never *fall*, which would more than counterbalance the benefit he would derive from the want of the fmall quantity of water that is required to flake it.

On the accounts, it may be admitted, as a general rule, that thole who can have acceds to line-flone which is free of fand, will fave a great deal in the carriage of it, by driving it in the ilate of *foells*; --and that, on the contrary, it will be molf economical in thole who can only get lime of a very fandy quality, to drive it in the flate of powdered lime.

From hence it follows, that the practice which now prevails, of carrying fhell-lime by water from one part of the country to another, is only an imaginary faving, obtained at a very high rifque, to thole who drive fhells of a fandy quality :—but a real and unequivocal advantage, of very high importance to the community at large, if these *fhells* are obtained from a pure lime-lione.

^{*} Thefe obfervations relate only to the faving of carriage to the farmer; an article of capital importance to him. It is proper now to take notice of fome other particulars that may equally affect him in this way, as well as in the application of the lime to his ground.

\$ 10.

A vague opinion, in general, prevails in every part of the country, that one fort of lime may be more valuable than another : but it does not appear that farmers have hitherto had almoft any sule to direct them
them in the choice of different forts of lime; fome effecting one fort *firengeft*, as they term it, and fome valuing another fort more highly, without being able to affign any fatisfactory reafon for the preference they give, in either cafe.

It is of importance, that this matter fhould be elucidated.

Although it does not always happen, yet, in many parts of the country, the real nature of lime is fo little underflood, that the weightieft lime is preferred, as a manure, to that which is lighter, becaufe it is imagined the first has more *jubfance*, and will therefore produce a more powerful effect upon ground, than the fineft and lighteft lime.

But, there feems to be no reafon to think, there is any difference in the fpecific gravity of different parcels of *pure* calcareous matter, when fully calcined; therefore, if there is any difference in the weight of various forts of line, it mult arile entirely from a variation in the quantity or *gravity* of fome extraneous matter that is mixed with the line.

And as *fand* is almost the only extraneous body that: is ever found in lime-flone, and is always of much greater (pecific gravity than pure quick-lime,—it follows, that the weighty lime only owes its fuperior gravity to a larger proportion of faud that is mixed with it.

But *fand* is of no value as a manure; fo that he who voluntarily purchafes this kind of lime, in preference to the other, is guilty of a great degree of folly; which will be the greater; it he has likewife to drive it from a confiderable diffance. It would be better for him, it he is determined to ufe nothing but weighty lime, to buy fuch as is pure; if it can be obtained, and mix it with find after he has got it home, fo as to give it the gravity required. Some might laugh at this, as a proot of his folly, and juftly : but, it is, furely, lefs toolih in him to do this, than to pay money for the fand which he would thus obtain for nothing, and deive it from a Q2 diffance. diftance, when he might have it at his door. This practice would allo be attended with the farther advantage of enabling lim to know exactly, what quantity of *real* lime he applied to his ground, as he would not be in danger of confidering the fand as a part of it.

§ 11.

Those who have accels to only one fort of limeflone, mult be contented with it, whatever may be its quality. But fuch as have an opportunity of chooling, may be benefitted by the following obfervations :

Pure lime-flone, when fully calcined and flaked, is reduced to a fine impalpable powder, that feels fort between the fingers, without the finalleft tendency to guittinefs. Such lime as contains fand, is never fo finenor lo fort, but feels gritty between the fingers, and is more or lefs fo as the fand is coarfer or finer, or in greater or finaller proportions.

The lime from pure lime-flone, is always of a bright white, when perfectly calcined, without a tendency to any colour. When it has any colour, it proceeds from the fand, or other uncalcareous matters in its compofition. There are, however, fome forts of fand, that are of fuch a pure whitenefs, as not to debafe the colour of the lime in the fmalleit degree; but thefe are rare : -And there are fome matters that alter the colour of the lime a good deal, without debafing its quality in any confiderable degree; but thefe are flill more rare than the former.

Hence it follows, that the beft lime for the purpole of the farmer, is that which is lighted, fofteft to the touch,² and whited. The more they deviate from either of thefe tells of purity, the worfe they are for him.

Softneß to the touch is not an unequivocal proof of the purity of lime. I have feet one kind of lime, that contained a large proportion of an uncalcareous impalpable powder, that was as not to the touch as the purelt lime; but this was a lingule reception to a rule that is very general.

\$ 12.

That the farmer may have under his eye, at one time, the feveral criteria of the purity of lime, that have been enumerated in different places of this Eday, I choofe to mention them here all at once. If he is attentive to mark thefe peculiarities, he needs be very little folicitous about examining the qualities of his lime, by any more minute or troublefome trials. They are as under:

If the lime-flone lofes much δf its weight in calcination, and the lime-flofels are extremely light; if the fhells require a very large proportion of water to flake them fully; if it is long before they begin to fall; if the lime-flome is not apt to run (or be vitified) in the operation of burning; if it falls entirely when it gets a fufficient quantity of water, after it has been properly calcined; if it fwells very much in flaking, and if the lime is light, fine to the touch, and of a pure white; he may be faitsfied, that it is extremely good, and may ufe it in preference to any other lime that is inferior to it in any of thefe refpects.

Thefe rules are perfectly fufficient to decide as to the comparative value of any two kinds of lime that may be appoled to one another and may be relied upon as fufficiently accurate for the ordinary purpoles of the farmers.

\$ 13.

But fuch as may diffeover a new quarry of lime flone, and who with to affectatin with certainty its real value, before they put themfelves to any expenfe about it, will do well to employ the following more accurate, and in that cafe, more eafy analyfis.

As all calcareous matters are capable of being diffolved in acids—and as no other earthy matter can be diffolved in them—it follows, that if a fufficient quantity of acid is poured upon any body that contains calcareous careous matter, this matter will be quickly diffolved, while the others are left behind ; and the proportions of each may be accurately afcertained.

To try the exact value of any kind of lime flone, or other calcareous matter, —take a quantity of aquafortis, or fipiti of falt 31 and having prepared them as in the margin, ‡ put them into a glafs or earthen veffel; —add to that, by little and little, a known quantity of the matter you mean to examine, which had been previoufly dried, and reduced to powder. After each addition, fuffer the violent effervefcence or ebullion that will enfue to abate before more is added. When the whole of the powder is put to the acid, and the effervefcence

* Nitrous acid.

+ Muriatic acid.

4 All the mineral acidsefferveice and unite with calcarcous earths. But as the vitriolic acid (fpirit or oil of vitriol) does not diffolce the calcarcous matter, but forms a new concrete, that ftill retains its folid flate, it is not fit for this experiment.

And as it fometimes happens, that a little vitriolic acid is mixed with either the nitrous or muriatic acids, it becomes neceffary to be certain that this is not the cafe, before they are employed in this experiment.

The caffielt way of trying if thefe acids are free from the witriolic, is to put a little clalk into them before yon employ them. If the acid is pure, the chalk will diffulve very readly; but if not, fome part of the chalk will fail to the bottom, in the form of a pure white fediment. When this is the cafe, add fmall bits of chalk, by little and little; till no more of that white fediment appears; a firer which, the acid may be kept for ufe, as (first) pure.

If the nitrous acid is fo flrong as to have a flight brown, or reddifh appearance, it ought to be diluted with water, till it afflinnes a greenifh look. As it is bought in the fliops, for the ule of dyers, &c., it is ufually weak enough.

If the muriatic acid is fo firong as to have a bright yellow colour, or emits funnes when the bottle is opened, it ought to be diluted, by adding water, till it affumes almost a colourle's transparency, with a very faint tinge of yellow.

When they are thus prepared, either of thefe acids may be ufed indiferminately for this experiment, as they are equally proper, vefence entirely fubfided, fir it about feveral times with a piece of tobacco-pipe, and allow it to remain for fome time, that the acid may act upon every particle of the matter, and thoroughly diffolve it. And to be certain that there has not been too little acid, put a few drops of frefh acid to the folution, which will excite a frech effervefence if the whole is not fully difolved. When no change is produced by this addition, it is a certain proof that the whole of the calcarcous matteris already diffolved.

Take then a piece of filtering paper, throughly dry, the weight of which is also known, fold it properly, and put it in a glaf stunnel ; pour the whole of the folution, with the matter that may have fubfiled, into the funnel, and allow it to filter through the paper flowly. When the fluid part has thos drained off, full up the filter again with pure water, to wath off the whole of the faline parts from the *refiduum*.* Add water, in this manner, till it comes off without any faline tafte; fuffer it then to drop off entirely, dry it thoroughly, and weigh the paper, with its contents. The difference between which, and what the powder and paper were at the beginning, is the whole weight of the calcareous matter; is that its proportion to the whole mais is perfectly alcertained.

In this manner 1 have examined a great many different kinds of kines-flone, and have tound them vary in all degrees of purity, from fuch as were entirely foluble in acids, as fogar or falt is in water, to others that contained only one-twelfth of their weight of foluble matter, and eleven-twelfths of fand. The ordinary kinds of lines-flone costaia from one-third to twothirds of their weight of fand. Hard chalk is ufually a pure calcareous earth, foluble in acids; and fome forts of line-flone comy be met with that are equally pure, but thefe are rare. The only extensive line quarties

* The matter that remains undiffolved.

quarries of fuch pure linte-fone, that I have mer with, are at Sunderland, in the county of Durham, where there are feveral quarries of exceedingly fine linteflone, the beft of which belonged, in the year 1777, 10 Mr. James Galley of that place. There are fome quarries faither up the river WEAR, the flone of which is of a much inferior quality.

Were all the flones in the fame quarry equally pure, the above would be a perfect and unexceptionable method of afcertaining the purity of any lime-flone : But it often happens, that in a quarry of the very worft quality, there are fome pieces found that confit of pure fpar, that are entirely free of any mixture of fand ; and in other quarries of a better fort, there are often fmall veins of an impure fort of thone, mixed through the rock ; fo that if either of thefe fhould chance to be picked out as a fpecimen for trial, the refult would not be jnft.

To avoid falling into this miftake, any one who withes to make an accurate analyfis of any newly difcovered line.flone, will do well to take eight or ten flones from different parts of the quarry, that are fomewhat different in appearance from one another; and, having taken a chip from each, pound the whole together, to afford a proper fubject for the experiment.

The fame experiment might be tried with *lime*; but it is evident the proportions would be different in the fame flome, from what they would be if tried before calcination—as lime wants its fixed air, &c. which it had when in the flate of lime-flome. But as the lime is more liable to be varied by accidental circumflances, it is belt to try the experiment with limeflome.

\$14.

It is in general believed, that the imme made of the hardeft lime-flone is *fironger*, as it is called, by which is meant more powerfully efficacious as a manure, than that which is made from materials of a fofter nature. Hence it is in general allerted, that lime made from chalk, is much weaker, as a manure, than that which is made from harder lime-flone.

Nothing, however, can be more erroneous than this hypothelis. In the former part of this Eflay, I have had occafion to explain pretty fully what is the real difference between chalk and lime-flome; and nothing can be more certain, than that the lime made of chalk is purer than that made from almoft any lime-flone, and contains a much larger proportion of calcareous matter; on which account, it mult be more efficacious as a manure, than any of thefe more impure kinds of lime.

The hardeft lime-frome that I know, is that belonging to Mr. Galley, at Sunderland. Its external appearance rather referables finit than lime-flone; y et the lime made of this exceedingly hard flone, is as light, as white, and as foft to the touch, as the pureft chalk-lime. It differs not from that in any refpect, infomuch that I dety the greateft connoifieur in the matters to diffuguith between it and the pureft chalklime, when pericétly calcined, by any other means than by the pieces of flint that are fo often met with among chalk-lime.

And from this lime, obtained from thefe very hard Rones, as perfect chalk may be artificially made by the fimple procefs definited § 24, as was ever obtained from any quarry in England.

From these confiderations, therefore, I am obliged to conclude, contrary to the common opinion, that chalk-line is, almost in all cafes, more efficacious as a manure, than any line obtained from lime-flone, in equal quantities ; as it is extremely rare to meet with a lime-flone that contains near fuch a large proportion of calcareous matter ; on which account it ought always to be preferred by the farmer, where both can be had at the fame price.

\$ 15.

\$ 15.

We know little certain about the mode in which, lime operates, excepting that it acts merely in confequence of its being mixed with the foil in fubflance. If a heap of lime, of a confiderable thicknefs, flah have lain ever fo long upon one fpot, and be afterwards carried clean away from it, fo that none of the particles of the lime remain to be mixed with the' foil, --that fpot will not be richer, or carry more luxuriant crops, than the places around it; which, every one knows, is not the cafe with regard to dong.

Again—If lime be foread upon the furface of the foil, and allowed to remain there, without being ploughed in, its effects will fcarcely be perceived for feveral years, till it has had time gradually to fink through the fward, and mix with the foil ; after which, its effects begin to be perceived, although muchlefs fenfibly than if the fame quantity of lime had been intimately mixed with the foil by means of the plough and harrow.

I am not a stranger to the improvements that have been made in Derbyshire, by means of lime, without the plough ; but this is no exception to what I have faid. The effects are flow though certain. Those who inhabit countries that admit of the plough, are often advifed to lay lime upon the grafs, and are made to believe that their pafture will be inftantly mended by it, nearly in the fame perceptible manner as if it had been dunged. This, I myfelf have tried, and have feen it tried by others, but always found that the grafs for the first year was rather hurt than benefitted by it ; nor was it fo much improved in fucceeding years, as if the fame quantity of lime had been applied, and intimately mixed with the foil. In this mode of applying lime, therefore, it is long before it yields a proper return; and is not to be recommended to a poor man, unlefs where neceffity obliges him to practife it.

\$ 16,

\$ 16.

If, then, lime acls upon the foil more efficacionity in confequence of being initiately mixed with it, we may naturally conclude, that it will produce a more femibile effect, when it is reduced to exceedingly fmall particles, than when it is applied to the foil in larger lumps; as thefe do not admit of being fo intimately mixed with the particles of the foil.

But no method has ever yet been difcovered for reducing calcareous matter to fuch fmall component parts, or of fpreading it fo evenly over a field, or of mixing it fo intimately with the foil, as by calcination. Accordingly, it is found, that *lime* will produce a very fenfible effect upon the foil, when applied in much fmaller quantities, than any other calcareous matter whatever.

Confidered in this view, it can never be expected that lime-inlone, reduced to powder by any kind of mechanical triture, will produce, fuch a fenfible effect upon the foll, as the fame quantity of calcarcous matter in the flate of *lime*, *if properly applied* , becaufe it is impofible, by mechanical means, ever to reduce it to loch a fine powder as it naturally falls intoaffer calcination.

\$ 17.

Much, however, depends upon the mode of applying the lime to the foil, after calcination. If it is fpread as foon as it is flaked, while yet in a powdery flate, a very fmall quantity may be made to cover the whole forface of the ground, and to touch an exceedingly great number of particles of carth. But if it is fuftered to lie for fome time after flaking, and to get fo much moifture as to make it run into clods, or cake im large lumps, it can never be again divided into fuch fmall parts ; and, therefore, a much greater quantity is neceffary to produce the fame effect, than if it had been applied in its powdery flate.

But

But if the foil is afterwards to be continued long in illage—as thefe clods are annually broken fmaller by the action of the plough and harrows, the lime mult continue to exert its influence anew upon the foil for a great courfe of years:—it will produce an effect nearly fimilar to that which would be experienced by annually frewing a fmall quantity of powdered lime over the furface of the foil. But as the price of the lime mult, in the first cafe, be paid by the farmer altogether, at the beginning, which only comes to be fucceffively demanded in the other cafe, this deforwes to be attended to, as it may become a confideration of fome importance where lime is dear, and money not very plentiful.

\$ 18.

In few particulars are practical farmers more divided in opinion, than about the quantity of lime that may be laid upon an acre of ground with profit, or even with fafety. Some require that it should be applied in fuch fmall quantities, as thirty or forty buffels to the acre ; and aver, that if more is ufed, the ground will be abfolutely ruined : while others maintain, that ten times that quantity may be applied with fafety.

A great variation imay, no doubt, be produced in this refloced, by a difference in the nature of the foil, in the flate of collure it is under at the time,—in the quantity of calcareous matter with which it may have been formerly impregnated ;—and perhaps a variation may fometimes arile from other circumflances that have never yet been attended to.

A difference will likewife arife from the quality of the lime that is applied, and from the manner in which it is employed. Some kinds of lime contain, perhaps, ten times more calcareous matter than other kinds ³² And it has been flown above, that a very great difference may atile from the mode of applying the lime. Confidering Confidering all thefe circumflances, it would appear a little prefumptions in any one to preferibe politive rules that fhould be generally adopted in this refpect. This 1 fhall not attempt—but fhall relate, with candour, fuch obfervations as have occurred to myfelt, in the courfe of a pretty extensive experience of this manure.

\$ 19.

It is common to hear those, who have had little experience of lime as a manure, recommend very great caution, left too great a quantity be employed, for fear of burning the fail, as they express it. This idea of burning has been evidently adopted, from what is experienced by applying cauftic lime to animals or vegetables, in large quantities, as it often corrodes and fhrivels them up, and produces other effects which greatly refemble those of fire : But it cannot produce any fuch effects, unlefs there are vegetables growing upon the foil at the time. In that cafe, the vegetables might, indeed, be corroded by the lime, if rain fhould fall immediately after it was fpread, when newly flaked ;-but as it lofes this fiery corrofive power in a few days after it is fpread, nothing of that kind can be expect d to happen to the foil. Accordingly, we never hear of crops being burnt up with too great a quantity of lime, in those countries where it has long been used as a common manure-although it is there often employed in much larger quantities than in any other places where it is more rare.

I myfelf have had the experience of lime in all proportions, from one hundred to above feven hundred buthels to the acre, upon a great variety of foils; and have always found, that its effect in promoting the fertility of the foil, has been in proportion to the quantity employed, other circumflances being alike.

The expense in most cases prevents farmers from employing this manure in greater quantities than those above above mentioned ; but accidental circumftances clearly fhow, that if it were applied in much larger quantities, the effect would only be to promote the luxuriance of the crop in a higher degree.

\$ 20.

A gendeman of my acquaintance, in whofe veracity I perfectly confide, happening to be from home when a large field was limed; and having no occalion for the whole quantity of lime that had been brought for that purpofe, and laid down in one corner of the field, his fervants, without driving it away, mixed what remained with the foil, although the lime lay there about four inches thick over the whole furface. The effect was, that for many years afterwards, the grain in that place was fo immoderately luxuriant, that it fell over, and rotted before it came to the ear. After many years, this luxuriance abated a little, fo as to allow the grain to ripen ;--but it was there always much more luxuriant than in any other part of the field.

An accidental experiment, nearly fimilar to this, fell under my own obfervation. It happened that the fervants of another farmer laid, by milfake, a few heaps of lime upon a grafs field that he did not intend thould be broken up at the time. The milfake was foon difcovered, and no more lime was laid down at that place, and the few heaps (about a bufhel in each) were allowed to lie, neglected, without being fpread. The field was paftured upon for feven or eight years after that, before it was converted into tillage; and the heaps were by that time become fo flat, and fo far fink into the ground, that they could hardly be difcovered.

Before it was ploughed up, the whole of the field was limed, and this part of it equally fo with the reft; nor were the old heaps touched till the plough went through them in tilling the field, when the lime was there these turned up, with only a very fmall mixture of foil. The confequence was, that at every one of the heaps, a toft of corn fpring up with fuch luxuriance as to be entirely rotted before harveft ;—and for many years afterwards, thefe tufts could be diffinguifhed from the other parts of the field, at a very great diffance, like fo many buttons on a coat ;—and, perhaps, continue fo to this day.

From thefe experiments, as well as other confiderations that will afterwards occur,—there feems to be reafon to conclude, that on foils which do not naturally abound with chalk, or other calcareous matter, there is lefs danger in giving too much lime, than in applying too little; except in thole cafes where an overluxuriance is dreaded.

§ 21.

I have often heard it urged, as an objection to the ufe of lime as a manure, that although it does indeed promote the fertility of a foil, in a higher degree at firft, yet, in the end, it renders it much more flerilthan formerly; on which account, they fay, it ought not to be at all employed.

This, like many other objections to ufeful practices, takes its rife entirely from the avarice and unfilifulneels of thole who complain. It is chiefly heard of in thofe parts of the country where it is not uncommon for a farmer, after once liming a poor foil, to take fifteen or fixteen crops of oats fucceflively, without any other dreffing or alternation of crops. It mult be a good manure that enables thefe foils to produce fach a number of fucceflive fecurging crops of any fort : But it would be a marvellous one, indeed, if it thould prevent thole fields from being exhaulted by them.

But, is it not well known, that in all the richeft and beft improved parts of the country, lime has been long employed as a manure ? Yet, fo far are thefe foils from being rendered fleril by it, that it is doubtful if any art, without the affiftance of lime, or fome calcaroous matter; could ever have brought thefe fields to their prefent degree of fertility. Thofe, therefore, who complain of the hurtful effects of lime as a manuer, proclaim what they ought to conceal,—that they have had in their poffefiion a treafure, which might have enriched their pofferity, but which they have idly fquandered away in their own life-time.

\$ 22.

We are not only unacquainted with the mode in which lime operates upon the foil, but we are even, in a great measure, ignorant of the actual changes that are produced upon the earth, after this manure is applied. So much time is neceffary to difcover thele, —and fuch accuracy of obfervation is required, that it will, perhaps, be long before the whole thall be fully afcertained. I fhall mention a few that have occurred to myleff.

It is often afted, how long the effects of line may be perceived on the foil ? and, if by this queffion it be meant to afcertain the length of time that the effects of line will be perceptible in promoting the luxuriance of the crop after one manuring, it is no wonder that very different anfwers fhould be given, as the effects mult vary with the quantity or quality of the line employed; the nature of the crops that follow, and many other circumflances, that it would be impoffible here to enumerate.

But if it be viewed in another light; if fine be upploted to alter the foil, fo as to render it fufceptible of being affected by other manures in a more fenfible degree, fo as to make it capable of producing crops, that no art could otherwife have effected, and to admit of being improved by modes of culture that would not otherwife have produced any fenfible benefit; the anfwer to the quettion would be more eafy, as, in this light, it is pretty plain, that its eff. Cls will be felt, perhaps, as long as the foil exitfs. I believe, I believe, farmers are feldom accuftomed to confider lime, or other calcareous manures, in this laft point of view; a lathough, when it comes to be inquired into, I doubt not but this will be found to be by far the moft valuable effect of thefe manures. A lew facts will beft illuftrate my meaning :

In Derbythire, the farmers have found, that by fpreading line in confiderable quantities upon the furface of their heathy moors, after a few years, the heath difappears, and the whole furface becomes covered with a fine pile of grafs, confilting of white clover, and the other valuable forts of patture-graftes. This fhows, that line renders the foil untriendly to the growth of heath, and friendly to that of clover.

It is found by experience, that in all porous foils, which are not exposed to too much dampucfs, in every part of Scotland, where lime has not been employed, heath has a natural, and almost irrefiftible propenity to eftablib itfelf. In thefe parts of the country where lime has been much ufed as a manure, we find, that the fields may be allowed to remain long in grafs, without being covered with that noxious plant.

Again :--It is well known by thofe who have been attentive, and have had opportunities of obferving the facil, that peas, of any fort, can never be fuccefsfully cultivated in any part of the country, where the fail is not of a very fitrong clayey nature, or where lime or other calcarcous manures have never been employed. If the ground be made as rich as polifible with common dung, although the peas, in that cafe, will vegetate, and grow for fome time with vigour; yett, before they begin to ripen, they become blighted ; ufully die away entirely before the pod is formed, and but rarely produce a lew half-formed peas.

But if the ground has ever been limed, although, perhaps, at the diltance of thoufands of years before that period, it never lofes its power of producing good crops of peas, if it is put in a proper tilth for carrying when at that time. Again :-- Again :--In countries that have never been limed, the kinds of grafs that fountaneoully appear, if left to themfelves, are the fmall bent-grafs and feather-grafs. In places where lime has ever been ufed, the ground, if exhaulted, produces fewer plants of thefe graffes ; but in their flead, white clover, the poa and fefcue graffes, chiefly abound.

The foil, in either of thefe cafes, may become equally poor ;---that is, may produce equally [canty crops : But, the means of recovering them will be fomewhat different. In the laft cafe, a fallow feldom fails to prove beneficial. In the firft, it is often of no effect, fometimes, even hurtful. In the laft, a moderate dreffing of dung, produces a much more fenfible and lafting effect, than in the other. In the laft, the quality of the grafs, as well as its quantity, rather improves by age. In the firft, thefe circumflances are reverfed.

I might mention feveral other obfervations, tending, to fhow that ground, which has been once impregnated with calcareous matter, acquires qualities from that moment which it did not polifels before, which it ever afterwards retains, and never returns exacily to its former flate. But, I have faid enough to fuggeft this idea :--future obfervations will flow how juilly it is founded.

\$ 23.

Although lime has fuch powerful effects on the foil, it does not feem ever to incorporate with the mould, fo as to form one homegeneous mafs; but the lime remains always in detached particles, which are larger or fmaller, in proportion as it has been more or lefs perfectly divided when it was fpread, or broken down by the fubfequent mechanical operations the foil may have been made to undergo.

Hence it happens, that in ploughing, if there chance to be any lumps of calcareous matter in a dry flate, upon upon the furface, they naturally tumble into the bottom of the open furrow, as foon as the earth is edged up upon the mould-board, fo as to fall into the loweft place that has been made by the plough before the furrow is fairly turned over.

In confequence of this circumftance, it must happen, that, in the course of many repeated ploughings, more of the lime will be accumulated at the bottom of the foil, than in any other part of it. And as, the plough fometimes goes a little deeper than ordinary, the lime, that on these occasions chances to be deposited in the bottom of thefe furrows will be below the ordinary staple of the foil, it will be useles for the purposes of the farmer. It is commonly thought, that the lime has funk through the foil by its own gravity ;-although it is certain, that lime is specifically lighter than any foil, and can only be accumulated at the bottom of the mould by the means above defcribed ; others think, that the lime is chemically diffolved, and afterwards deposited there; but this idea is not corroborated by the facts that have fallen under my obfervation. The directions that follow are equally applicable in either cafe.

To obviate this inconvenience, it behoves the farmer, in the first place, to be extremely attentive to have his lime divided into as finall particles as pollible at the time of foreading: For, if the fe are fulficiently finall, they incorporate for intimately with the mould, as to be incapable of being early detached from it. On this account, as well as others, it is always most advifable to foread the lime when in its dry powdery flate, immediately after flaking, before it has had time to run into lumps.

It is allo of importance to plough the foil with a more fhallow furrow than ufual, when lime is put upon it; efpecially the fuft time it is ploughed after the lime has been foread upon its furface : Becaufe, at that ploughing, the lime being all on the furface, a larger larger proportion of it is turned into the bottom of the laft-made furrow, than at any fucceeding ploughing; and therefore more of it will be buried beneath the ftaple than at any other time, if the furrow fhall have been very deep.

This circumfance becomes more effentially neceffary in ploughing grafs-ground that has been newly limed; becaufe, in this cafe, the lime is lefs capable of being mixed with any part of the foil than in any other.

It also becomes extremely neceffary, in all fucceeding times, to guard as much as pollible against plonghing to unequal depths.

I have hitherto (poken only of *lime* as a manure ; but moft of thefe obfervations, it will appear, may be cqually applied to other calcarcous matters. That the comparative value of thefe, and the real difference between them, when compared feparately with lime, as well as with one another, may be fully inderflood, it will be naceflary to confider each clafs of thefe fubflances feparately, and point out with precision its peculiar difficience.

\$ 24.

OF CHALK.

All the writers on agriculture whom I have every yet met with, have confidered the feveral claffes of calcarcous fubblances as diffinct kinds of manures, and as poffeffing qualities extremely different from one another on many occafions. And hence it happens, that fometimes one of thefe, which chances to have become the favourite of the author, and fometimes another, is highly recommended, while the others are dcfpifed as ufclefs, or reprobated as pernicious.

In this manner, a very late Writer,* with whom chalk is a peculiar favourite, fays, 'I will lay it down

* The Author of the Complete English Farmer.

down as a certain and incontrovertible maxim, that obstk feedh from the pit, laid on and managed as before directed, in the proper feafon, will enrich every fort of earth it is laid upon ; and that *lime*, on the conrary, laid on at whatever time, or managed in whatever manner, will, after the firlt or fecond year, impoverith every foil it mixes with.

It would be no difficult matter to produce other authors, who, in a like decilive manner, reprobate the nfe of *chalk*, while they enlarge, without bounds, en the qualities of *lime*; and others who prefer *matle* of different forts, or fome of the other clalles of calcareous earths, as the molt valuable of all manures, while they condemn the others beyond all bounds of moderation.

The truth, however, is, that although thefe authors iman uses, the beneficial effects of which they may have often experienced; as they ufually condemn the others merely from early prejudices, or imperfect trials of them, which have not fucceeded, their decifions ought only to be confidered as a proof of their being unacquainted with the *real* qualities of the matters they condemn, and of that prefumptuous weaknefs which is ever the attendant of ignorance.

Nothing can afford a ftronger proof, that the author above mentioned was totally unacquainted, either in theory or practice, with the *real* difference between chalk and lime, than the pofitive diffinction he has made between thefe two fubflances as a manure.*

\$ 25.

It has been demonfrated in the preceding part of this Effay, that lime differs not in any of its qualities from chalk, except that its is deprived of its fixed air ; which can have no effect on it as a manure, becaufe it again abforbs that fixed air before it has been a few days

* The Reader ought to be informed, that the *lime* he conidemus, is lime made from the very *chalk* he fo much approves of. days applied to the foil. After this period, therefore, what was originally *lime*, is now chalk, and muth have the fame effects upon the foil *in every refpect*, as an equal quantity of chalk, *equally fpread upon it*, would have had.

It is eafly, however, for those who attend to the prastice of this Gentleman, to account for his partiality to chalk. The quantity of chalk he recommends, is twenty-five loads per acre; which, I fuppole, may be about twelve hundred buthlets. He advices only ten or fifteen buthles of lime. Is it furprifing that the effects of thefe two dreflings flould be extremely different ?

He ventured once to give a field of clay a dreffing of fixty bufhels of lime; after which he took,

Ι.	wheat,	produce	16 bushels,
2.	oats,		4 quarters,
3.	barley,		5 bufhels,
4.	clover,		worth nothing.

Hence, fays he, the lime has ruined my foil.

The foil was acknowledged to be poor—Inflead of fixty, it is doubtful if fix hundred buthels would have been fufficient to make it produce good crops, under a management fo execrable in other reforcts.

But-to leave off these ungracious strictures, I now proceed-

\$ 26.

CHALK, as has been often faid in the courfe of this Effay, is a pure calcareous earth, haftly concreted. Sometimes it is mixed with a finall proportion of argillaceous* matter, in which flate it approaches to the nature

* A load, I underfland, to be a waggon-load---which, I fuppole, may contain between five and fix quarters.

* Clayey.

nature of *marle*. In either the one or the other of these flates, it is employed as a manure in the countries where it abounds.

Chalk differs not from lime in any particular that can affect the farmer, unlefs it be that *lime*, by being in the flate of a fine powder, admits of being more equally fpread upon the ground, and more intimately mixed with the foil, than $cakk_s$ —from whence it follows, that a much fmaller quantity of lime may be employed fuccelsfully as a drefling for ground, than could pofibly be the cafe with chalk.

In order, therefore, to make chalk produce the greateft polible efficit upon the foil, it becomes needfary to reduce it into as fmall pieces as can be done ; fo that it ought to be an object of great importance to thofe farmers who have an opportunity of employing this fubftance, to difcover what is the eafielt and leaft expensive method of reducing it, as foon as pollible after it is fuperad upon the foil, into very fmall portions.

Chalk is fuch a porous fubftance, that when in its native bed, after long and continued raines, it is found to have imbibed a great deal of moifture, by which it affumes a fortifh feel to the touch.

But if chalk be dug out of the pit and dried flowly and perfectly by the heat of a fummer's fun, its pores become in fome degree contracted 3—it refifts, in a great meafure, the freth admiffion of water, and acquires a much greater degree of hardnels, than when it was originally dug from the quarry.

On the contrary, if it be taken from the pit during the wet weather in winter, and expoled to the rains that ufually fail at that feadon, it has never time to dry—its pores remain quite full of water; and when the froit comes on, that water in the act of freezing, being greatly expanded, burfls it forcibly a funder, and makes it crumble down into a flimy kind of powder. And as the pieces that may remain undecompoled, continue to abforb more as the rains fail from the heavens, heavens, the frofts that may fucceed occafion a new diffolution;—fo that by thefe alternate rains and frofts, the whole is in time totally divided, fo as to admit of being pretty evenly foread, and mixed with the foil.

For thefe reafons, it is always expedient to dig the chalk in the beginning of winter, and to foread it immediately upon the field as well as can be done, fo as to expofe it to the viciflitudes of the winter weather, before it has had time to harden after being taken from the pit.

§ 27.

As the chalk ought always to be carried to the field while yet wet, it, in a great meafure, prevents thofe who may be at a diflance from the place where it is found, from being benefitted by this manure; becaufe the carriage of it would in thefe circumflances be extremely burdenforme.

To obviate this inconvenience, it becomes a very economical practice, to reduce it to the flate of lime before it is carried home: For, in this way, the weight is not only much diminifhed by the diffication of all the moilture from the chalk, but it can all o be carried home in fummer, when the weather and roads are at the belt; and a much fmaller quantity will produce an equal effect, than when it is in the flate of chalk.

Thole, therefore, who have no other calcareous manure within reach of them but chalk, when that is at a confid-rable diflance, ought always to drive it in the flate of lime. But thole who are close by the pit, will, in general, find it more economical to employ it in the flate of chalk.

§ 28.

Chalk fo much abounds in the fouthern parts of Britain, that fhips fometimes bring it as a ballaft to the north ; on which occafions, it may be purchafed at a moderate price by the farmer. But although it contains contains perhaps nearly an equal quantity of calcareous matter as the fame bulk of fome very pure kinds of lime, yet it will not be good economy in him to purchafe it at the fame price with the lime, as at leaft three or four times more chalk than lime will need to be applied to his foil, before it produces an equal effect ; For, as it is impolfible to get that hard dry chalk reduced to fmall enough parts, a great quantity mult be applied before it can produce any fenfible effect ; and although the effects of this manure may be latting, yet it is never any thing near equal to lime, if applied in equal quantities.

Another calcareous matter, of great utility as a manure, is *marle*—The diffinctive properties of which fall now to be confidered.

\$ 29.

OF MARLE.

Few fubflances appear under a greater diverity of forms, than marle. Hence it is ufual for writers on agriculture, to enumerate, as difind manures, the feveral varieties of this general clafs of bodies. But as all the different kinds of marle that have hitherto been diffowered, may be reduced to two general claffes, viz. *earthy* marles, which are always found in folfil ftrata under the earth, and *fhell* marle, which always retains evident marks of its animal origin. I thall confider each of thefe feparately, as diffind fubflances.

\$ 30.

Of Earthy or Foffil Marle.

The varieties of this clafs of bodies are diffinguifhed by names fuggelled by the appearance they allume when fred hug from their native beds. When they are four and of an uniform texture, they are called clay marks; when firm and hard, flone marks; when their thefe affume a thin foliacious appearance, they are denominated flate marles, and fo on.

But whatever appearance they affume when fielh dug, or by whatever name they are known, they all agree in this, that if they be exposed for a fufficient time to the action of the air, they crumble into fmaller parts, and fertilize the earth to which they have been properly applied.

The ingenious Dr. Ainflie has demonfrated, by an accurate fet of experiments recorded in the Phylical and Literary Effays, in the third vol. of my Agricultural Effays, That all the varieties of this class of bodies contain a confiderable proportion of clay, united with calcareous matter; whereas lime-ftone, if it does not confilt of pure calcareous matter, is ulually united with fand in various proportions.

The calcareous matter in marle, does not differ in any tefpeck from that in line-flone, and its proportions in many cales is the fame in marle as in line-flone; fo that the difference between the appearance and quallities of thefe two fubliances, arifes entirely from the nature of the heterogeneous bodies mixed with the calcareous matters.

When mark is expoled to the air, the clay, in its composition, abforbs the moisiture that falls from the clouds—fwells with it—becomes fort—and, gradually lofing its cohefion, crumbles to pieces. If lime-flome is explode to the air, the fand in its composition is not in the least affected by moisture, and it retains its original figure and dimensions for a great length of time.

When fand is mixed with the clay that enters into the composition of marle, it affumes a ftony-like appearance, and is more or lefs firm, according to the quantity of fand, or other circumflances. But where there is clay at all in the composition, it will be gradually foftened by water acting upon it; and it is owing to this circumflance alone, that ftone-marles fall in time to pieces when exposed to the air. But But if marke be exported to the adition of a moderate fire, the clay in its composition becomes hard—it is no longer capable of abforbing water, or of being aff-cled by it in any degree; fo that the marke, if not of a very pure fort, or fuch as contains only a very finall proportion of clay mixed with the fand in its composition, will become firmer after burning than it was before, and be in this flate with more difficulty reduced to powder, which is the reverse of what happens with limeflone.

Marle, therefore, is fit to aft as a manure, without any other preparation than digging it from the pit, and foreading it upon the ground; whereas lime-flone always requires to be reduced to a powder, either by burning or otherwife, before it can be of any ufe in that way.

But as lime-flone is at once reduced into much fmaller parts by calcination than mark ever can be brought to at firit, a much fmaller proportion of lime may be equally fpread over an acre of ground, than of marle; and therefore it will produce, in equal quantities, a much more fenfible effect.

\$ 31.

The differing reader, who attends to thefe circumfances, will eadly perceive the reafons for all the pocultarities of practice that prevail with regard to the application of lime and marke, and be able, without embarraffment, to judge in what cafes it may be moft for his profit to employ the one or the other of thefe manures, when they are both within his power.

He may afcertain the propertion of calcareous matter contained in the marle, by the fame procefs already deficibed for trying lime-flone, page 72, and thus compare the intrinfic value of the lime and marke in any cafe. For this is always in proportion to the calcareous matter contained in either.

He will eafily perceive, however, that the fame

quantity of calcareous matter in the flate of *lime*, wild produce a much greater effect than when it is in the flate of *marle*; becaule it is divided into infinitely fmaller particles, can be more equelly foread upon the ground, and more intimately mixed with the foil.

⁶ Hence it univerfally happens, that a much larger quantity of marke is applied at one drefling, than of line. From one to two hundred cart-loads of marke is a common drefling to an acre, that is, from three thoufand to fix thouland buffhels; withreas, from thirty to three hundred buffhels of lime is a common drefling for an acre of ground.

In thefe proportions, it is reafonable to think that the effects of the marke will continue to be longer felt than thofe of the lime : For, as the marke is gradually broken into finaller pieces every year, thefe will fucceffixely mix with the foil, and produce an effect nearly fimilar to what might be expedded from an annual drefting of lime.

It may likewife be expected, that a full drefing of marke, in the proportions above named, will produce a more capital improvement upon light fpungy grounds, than an ordinary drefing of lime ; --becaule, independent of the calcarcoix inatter, the large proportion of elay applied in this manner, may produce forme alteration on the quality of the foil. This alteration, however, will be different, according to the nature of the extraneous matter contained in the marke.

But as all markes contain clay, it is natural to think that clay laads will not be benefitted at all by this circumflance, as in thefe cafes the calcarcous matter alone in the marke will be to fuch foils en ufeful addition. Hence light land will be in general more highly benefitted by this manure than clay land, which has given rife to the following vulgar rhyme:

> He that marles fand, Will foon buy land; But he that marles clay, Throws all away,

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The truth, however, is, that clay is as highly benefitted by the calcareous matter in marle, as fand is; fo that a rich marle will be nearly equally beneficial in both cafes. But there are fome kinds of elays that are very free from any mixture of fand, and affunce the appearance of marle; and are fo called, although they hardly contain almolt any calcareous matter at all. Thefe may perhaps, on ofome occafions, be an infeud addition to light foils, and worth the expense of carrying to them when near, but could fcarcely be of any ufe at all upon clayer foils. It has probably been fome poor kind of marle of this fort that has given wife to the proverb abovg quoted.

\$ 32.

I thall not pretend to preferibe politive rules for determining when the one or the other of thele fubfances, line or mark, ought to be preferred as a manure; as a decilion in favour of the one or the other mult, in a great measure, depend upon the fituation of the place where they can be both obtained; the purity of either of them refpectively; the price at which they may be purchafed, and the expenie of carriage : all thefe circumitances may be belt alcertained by every individual for himfelt.

But I may be allowed to obferve, that it argues a great want of knowledge of the real qualities of thefe fubfances, when a man prefers the one of thefe, and condemns the other, in all cafes. For it is merely a matter of calculation, when the one, or when the other, may be molt valuable to any particular perfon.

If the marle be tolerably rich, and can be obtained at little experies near the field in the proportions ufually employed, it will be, in general, more advantageous to the poffelfor, who has a profpect of enjoying his farm for a long time, to ule marle in preference to lime.

But when it must be brought from a distance, lime,

in all cafes, will be cheaper, and on that account better than marle.

If marle contains a great proportion of clay, it may be worth the expense of driving to a light foil on fome occations, even where lime could be procured as cheap: But, on all occations, if the fame quantity of calcareous matter in the flate of lime can be obtained at the fame price, *that* will be a much more beneficial manure for clayey foils than marle. Impure marle is indeed feldom worth the expense of carting on a elayey foil.

Some readers will be much diffatisfied at reading this fhort account of the nature of marle, and its operation as a manure. For as they have been accuftomed to look upon this manure as poffeffing fome very fingular qualities peculiar to itfelf, and to think that it differed from lime in fome very effential respects, and would produce effects upon the foil nowife fimilar to that which would be produced by lime in any cafe ; they will feel a kind of uneafinefs at being obliged to ftrike this one off their lift of diffinct and feparate manures. But it is the bufinels of true philosophy to eradicate that spirit for mysterious credulity, which is fo apt to lull the reafoning faculty afleep, and make the mind reft fatisfied with the contemplation of ideal phantoms created by the fancy, inftead of real objects. of uleful knowledge.

\$ 33.

Of Shell Marle.

Shell marle is always found in low places, that either are, or have been covered with water. It is a whitil powder, that has been formed by the gradual decomposition of fhells, in the courfe of many ages. It is, therefore, a pure calcareous matter, without any other mixture than the mud and other fediments, that may have funk to the bottom of the water, in ponds where it has been formed. As As the proportion of fediment that may have mixed with the fhells, may be very different in different fituations; thiskind of marle, like all others, may be more or lefs pure, and, of confequence, of greater or fmaller value to the farmer. Its purity may be determined by the mode preferibed, page 72, and its value thus afcertained with precifion.

It is ufually a light, fpungy fubflance, very flightly coherent; and contains more calcareous matter in proportion to its weight, than the common forts of lime. And as it admits of being fpread as equally as lime, it may in general be carried with profit as far as lime.

But as it is more fpungy than lime, perhapsa fmaller quantity will fill the meafure; on which account, the prime cold of the fame quantity of marle ought to be a little below that of lime, to be equally prefitable to the farmer.

Shell marle, however, cannot be carried fo far with profit as fhell lime of the belt fort; as this laft, in that flate, wants a great proportion of its moifture, air, &c. which greatly diminifies its weight.

It is, nevertheles, a very great treafure to thole who can difcover it, as it is almoft in all cales of equal value with line, produces the fame effect upon the foil, admits of being equally eafily foread, and can for the moft part be obtained, upon the fpot, at a much fmaller expense.

But, in lituations where fuel is fcarce and dear, it is of much greater value than the beft lime-flone, and ought to be prized accordingly by every poffelfor of ground: not ought any one, in fuch a fituation, to omit fearching diligently every place where there is the fmalleft probability of finding it.

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\$ 34

Of Shelly Sand.

On many parts of the fea-coaft, great beds of filelis are to be found, which have been broken into fuch finall parts as to aflume the appearance of fand. This is a rich and valuable manure, that deferves to be highly prized by thofe who are within reach of it; but, it is too often neglected and unobferved, as this kind of fand has, on many occafions, very much the appearance of ordinary fand.

This may readily be different, by pouring a little aqua-fortis, or any other mineral acid," upon the fand you with to examine. If it contains fhells, an effervefcence will enfue; and the proportion of calcarcous matter contained in any fort of fand, may be alcertained by the fame procefs already fo often referred to, r.2. Nor ought this trial ever to be consitted before the fand is employed as a manure 2 becaule, a very fmall proportion of fhells will make it effervefce violently, fo that the degree of effervefcence is no proof of its purity, and becaufe the proportion of fhells varies in all pofible degrees.

If the thells are broken into very finall fragments, and if the proportion of fand be inconfiderable, it will be nearly as valuable as lime, and may be driven to a great diltance with profit. If the proportion of ordinary

* Many perfoss make this trial with enegar, infead of the mineral acids jout this ought never to be done, as it often happens, that vinegar makes no fenfible effervefcence with calcareous tiblances. I would, therefore, advice every country gentleman, to keep a phial of aqua-fortis, or muriatic acid, slavays by him, for making trials of calcareous fublances: the expende is next to nothing ; and I am purfunded, from the want of it alone, many perfors have failed to make difcoveries of calcareous matters that might have been of high importance to themfelves and families.

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mary fand be very great, the expense in using it will be greater, as the quantity must be confiderably increased.

⁷ But as it may, for the molt part, be procured at little expense, those who are possible for a fit, are ufually able to employ it in great quantities, in which case, it will produce amazing effects, efpecially upon fitrong clay-land.

A much fmaller quantity of calcareous matter in this flate, will produce a more fenfible effect, than when it is in any fort of earthy marle; becaule it admits of being more equally fpread upon the ground, and more intimately mixed with the foil. Thofe, therefore, who are upon the fea-coaft, ought to fearch for it with care, as they will ufually obtain an invaluable treature when they difcover it.

This fort of fand is much more common on the eaft coaft of Scotland, than is ufually imagined. All along the coaft of Fife, effecially about St. Andrew's, the fand upon the fhore is nichly impregnated with fhells ; -but, it has never there been employed as a manure. On the north coaft of Aberdeenfhire, fhelly fand abounds, and has been of late employed as a manure, with the greateft fuccefs, by a gentleman diftinguilhed for his knowledge and public fpirit in that corner. It is likewife found in Banff-fhire, where it has been applied with the higheft fuccefs. And all along the coaft of Southerland and Caithnels, the fands upon the fhore confit almott entirely of thells.

Thefe are treafures which will earich pofterity, although they are at prefent, in a great meafure negled. I mention them here, to induce my countrymen, not to negled: a treafure of fuch ineffimable value. But on the welf coalts of Scotland, and among the iffands, fhelly-fand much more abounds, and its effects as a manure, are much more generally known than on the eaft coalt, fo that it is there univerfally employed as the molt efficacious manure with which they are acquainted. Its effects upon fome of their heathy molfw moffy foils, appears to be, in fome cafes, little fhort of enchantment.

The ingenious Mr. Craik, in Dumfrieshire, fo well known for his judicious improvements in the drill hufbandry, has, I am told, employed this manure for a longer time, and in greater quantities, than any other perfonin Scotland, and has been highly benefitted by it. I wifh to produce fuch a refpectable authority, with a view to induce others to follow his example.

\$ 35.

Mr. Arthur Young, in one of his Tours, mentions a bed of fhells near Colchefter, in Effex, which the inhabitants diffinguifh by the name of *Cragg*, and employ as a manure, with great fuccefs. From his account of this fubltance, it would feem doubtful, whether it was a real calcareous matter or not. But he only tried it with vinegar, an acid too weak to produce any fentible effect on many forts of calcareous matters, in certain circumflances. There is little room to doubt, but that, with a mineral acid, the effervefcence would have been fufficiently violent.

\$ 36.

In fome places, there are found large beds of oyfterfhells, almolt entire. Thefe are fo large as to require to be broken into fimaller fragments, before they can be profitably employed as a manure.—And as thefe may be ealify calcined, they ought always to be reduced to the flate of lime before they are ofed. Whoever finds a bed of thefe fhells, finds a lime-quarry of the moft valuable fort, and ought to value it accordingly.

It may be fometimes neceffary to burn fhelly fand into lime; and this may, on extraordinary emergencies, be practified, although it is rather a troublefome operation : For, as the incoherent fand always mixes with the fuel, and extinguilhes the fire when in its native.

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five flate, it becomes neceflary to reduce it first to fome degree of confiltency.—This may be effected by kneading the fand with a little clay, and moulding it into the form fo bricks ; which, when dried, will retain their form fo long as to permit the first to act upon the hells, and burn them to lime, which may be afterwards flaked and ufed. A manufacture of this kind was for fome time carried on at the Duke of Bridgewater's great works, near Warrington, in Lancathire, as I am told, under the direction of the ingenious Mr. Frindley.

In fituations where lime-flone cannot pofibly be had, and where the carriage of *lime* would be extremely expensive, it may fometimes be advifable to burn fome of this fhelly fand into lime, for the *purple* of *building*, *3*—but if the lime is to be employed as a manure, it is a very idle and a ufelefs procefs: For, the burning, in this cafe, can only be of ufe in dividing the calcareous matter into finall parts, which has already been performed by Nature, when the fhells were reduced to the flate of fine fand.

\$ 37.

Of Lime-Stone-Gravel.

This is a manure little known in Britain, although it is common in many parts of Ireland. It is a hard fort of marle, that alliumes the appearance of fmall flones, or gravel, which, when fpread upon the ground, and mixed with it, gradually falls into fmaller pieces, and fertilizes the foil in proportion as it breaks down and mixes with it.

After what has already occurred, little needs be faid as to the qualities or mode of applying this manure. K

* The final quantity of elay that is introduced in this way, will not fendibly injure the power of the lime as a comment; for, before the fields can be fufficiently calcined, the clay will be burnt to fuch a degree, as to render it impervious to molfure, like fand. The reader will eafily be able to perceive, that if the pieces of which this gravel confifts are large, and diffolve but flowidy, the quantity applied at one dreffing ought to be great, and the effects will be flow and latting y-and, if the gravel is fmall, it will require a fmaller quantity, will operate more quickly, and laft for a fhorter time, like all other calcareous fubflances is the fame circumflances.

Thefe are all the varieties of calcareous matter that I have ever known to be ufed as a manure. They are all extremely ufeful in proper circumitances—perhaps equally fo, if thefe circumflances are duly attended to. To affit the farmer fill farther, the following general Aphorifins relating to the application of calcareous matters, as a manure, may be of ufe :

\$ 38.

APHORISM I.

There feems to be only one kind of calcareous matter; and all the varieties of calcareous fubliances that we meet with, are entirely occationed by a diverility in the nature of the extraneous bodies with which the calcareous matter is united, or a difference in the form it may appear in at the time.

Confidered as a manure, thefe extraneous matters may be more or lefs benchical, according to particular circumflances relating to the foil, &c. In all the foilif calcareous concretions, clay or fand feem to be the only extraneous matters worth attending to, neither of which can ever be of great confequence as a manure, although they may be more or lefs proper for different foils. In thefe calcareous fubfiances that belong to the animal kingdom, the fielthy parts of the animals may be formetimes united whit the calcareous, which will greatly promote their effects as a manure on every for of foil whatever. This does not, however, feem to be the cafe, either with fhell-marle, or

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fine fhelly fand; as, in both thefe cafes, the animals which once inhabited thefe fhells, have been fo long dead that no part of the fields fubliance can remain. But the recent fhells obtained from fifthing towns, operate much more powerfully as an animal manure; than as a calcareous matter, when firft applied.

It is not impossible but that man may in time fall upon fome contrivance for obtaining this animal calcareous manure in much greater abundance and perfection than it has hitherto been obtained. There is a fmall fpecies of freth water wilk .- which increases fo faft, as, in a furprifingly fhort time, to fill a confiderable space with folid wilks, if a few of them have been placed in a proper receptacle for that purpole, and water duly administered to them. If then ponds were prepared for this purpofe, and properly flocked with this animal, and if they were allowed to increase till a bed of them, of confiderable thicknefs, was accumulated, might they not then be taken out in abundance to be employed as a manure ? Thefe, if bruifed under a ftone like a tanner's wheel, to reduce the fhells to fmall fragments, would certainly form as rich and efficacious a manure as could pollibly be devifed : nor could there be any difficulty in difpofing the ponds in fuch a manner as to afford a conftant annual fupply.

It has probably been by a natural procefs fimilar to this, that all thofe beds of fhell-marle we now meet with, have been originally produced. This fpecies of marle is generally found to confift of the fhells of this fort of fmall wilk, more or lefs decompoidd. The animals which inhabited thefe fhells, have been once nourifhed by the water contained in thofe hollow places where this fort of marle is always found, and have probably been entirely dettroyed by fome accidental drought, which deprived them of the water neceffary for their exiltence, or to fome other difaltrous circumiltance that it is impofible for us now to point

OF QUICK-LIME

point out ; and the fhells remaining behind, gradually mouldered down to the flate in which we now find them.

APHORISM II.

The fame quantity of calcarcous matter, will, in all cafes, operate equally powerful on foils of a finitum quanty, when in a finitar flate. But thefe effects may be accelerated or retarded,—be more uniform or unegula, according as the calcarcous matter is more or lefs perfectly divided when it is first applied to the foil.

If the calcareous matter be divided into very finall Particles, fo as to admit of being equally (pread over 4 very large furface, a finall quantity of it will produce a much more fentible effect, than if the fame quantity of calcareous matter had been applied in large lumps, which could, in that cafe, have operated only upon a very few particles of the foil :— Therefore, *lime*, *fine foelly fand*, or *finell marle*, if equally pure, may be applied, with profit, in much finaller quantities than any other clafs of calcareous manures.

Hence alfo it follows, that if equal quantities of calcarecus matter are employed as a manue, that kind which admits of being moft minutely divided, will produce the greateft effect at the beginning; becaufe the feparate particles will be at liberry to aft on a much greater number of particles of the foil at once, than when it is lefs perfectly divided.

But if a fufficient quantity of calcarcous matter has been applied, when in pretty large maffer, fo as to cover the ground pretty equally; and if thefe lumps continue to diffolve in the foil in all after-periods, the effect of this drelling will be much longer perceived, than that of a drelling of calcarcous matter in fine powder, that thould produce at first an effect equal to this.—Perhaps, in this cafe, the virtue of every parice

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ticle of the calcareous matter will come, in time, to produce a full effect upon the foil, and benefit it nearly as much as an equal quantity of very finely powdered calcareous matter would have done, applied at different times. Stone and clay markes, therefore, are equally efficacious manures as powdered lime, although more flow in their operation.

But as lime that has been fuffered to run into fold cakes before it is applied to the foil, can neither be properly fpread upon it, nor has any chance of being diffolved by the action of the air afterwards, it never can be made to produce its fall influence on the foil; and therefore this mode of applying calcareous matter is the moft unecconomical that could ever be pracified.

\$ 40.

APHORISM III.

Calcareous matter, alone, is not capable of rearing plants to perfection : mould is neceffary to be mixed with it, in certain proportions before it can form a proper foil. It remains, however, to be determined, what is the due proportion of thefe ingredients for forming a proper foil.

We know, that neither chalk, nor marle, nor lime, can be made to nourith plants alone ; and foils are femetimes found, that naturally abound with the two furl of thefe to a faulty degree. But the proportion of calcarcous matter in thefe is fo much larger than could ever be produced by art, where the foil was naturally deflitute of thefe fublications, that there feems to be no danger of erring on that fide. Probably, it would be much eafier to correct the defects of thofe foils in which calcarcous matters fuperabound, by driving earth upon them as a manure, than is generally imagined, as a very finall proportion of it fometimes affords a very perfect foil. I thall illuftrate my meaning by a fewexamples.

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Near Sandide, in the county of Calthnefs, there is a pretty extentive plain on the fea-coad, endowed with a moft fingular degree of fertility. In all feafons, it produces a moft luxuriant herbage, although it never got any manure fince the creation, and has been for time immemorial fubjected to the following courfe of crops :

1/f, Bear, after once ploughing from grafs, ufually a good crop.

2d, Bear after once ploughing, a better crop than the first.

3d, Bear after once ploughing, a crop equal to the first.

4th, 5th, and 6th, Natural grafs, as clofe and rich as could be imagined,—might be cut if the poffeffor fo inclined, and would yield an extraordinary crop of hay each year.

After this, the fame courfe of cropping is renewed. The foil that admits of this ingular mode of farming, appears to be a pure incoherent fand, deflitute of the familied particle of vegetable mould i-but, upon examination, it is found to confit al mode the triefy of broken (hells: the fine mould here, bears fuch a fanal proportion to the calcarcous matter, as to be (carcely perceptible, and yet it forms the most fertile foil that ever 1 yet met with.

Thave feen many other links (downs) upon the fea fivre, which produced the most luxuriant herbage, and the cloft and fweetell pile of grafs, where they confilded of fielly land, which, without doubt, derive their extraordinary fertility from that caufe.

A very remarkable plain is found in the Ifland of Tir-eye or Tyre-ty, one of the Hebriles.—It has long been employed as a common, fo that it has never been diducted by the plough; and affords annually the moll hyperiant crop of herbage, confiling of white clover, and other valuable pafture-graffes, that can be net with any where.—The foil confils of a very pure field. fhelly fand. And the fineft crop of bear, without exception, I ever faw grow out of the earth, I found in the inland of Barra, one of the Hebrides, growing upon a bed of fhell-fand, in which, I could not perceive the finalleft, particle of earth. I do fuppofe, that the produce would have exceeded that of the beft crop of barley I ever faw, by two quarters, at leafl, per acre.—It had been maured with fea ware.

From thefe examples, I think it is evident, that a very fmall proportion of vegetable mould, is fufficient to render calcarcous mattera a very rich foil. Perhaps, however, a larger proportion may be neceffary when it is mixed with clay, than with fand; as poor chalky foils feem to be of the nature of that composition.

At any rate, however, from thefe examples, as well as from thofe that have occurred in the preceding parts of this Elday, 1 think we may be fufficiently authorifed to conclude, that there is no danger of ever applying calcareous fublicances to any foil in an over-proportion, if that foil was not originally impregnated with fome kind of calcareous matters, and if it finall be afterwards cropped in a judicious manner.

§ 41.

APHORISM IV.

Calcareous matters act as powerfully upon land that is naturally poor. as upon land that is more richly impregnated with those fubflances which tend to produce a luxuriant vegetation.

Writers on agriculture have been long in the cultum of dividing manures into two claffes, viz. enriching masures, or thofe that tended direcily to render the foil more prolific, however flerile it may bey-anong the foremoft of which was reckoned aurg,-and exciting manures, or thofe that were fuppofed to have a tendency to render the foil more prolific, merely by adiing ing upon those enriching manures that had been formerly in the foil, and giving them a new (timulus, foas to enable them to operate a new upon that foil which they had formerly fertilized. In which class of fitmulating manures, *time* was always allowed to hold the foremost rank.

In confequence of this theory, it would follow, that lime could only be of ufe as a manure when applied to rich foils, and, when applied to poor foils, would produce hardly any,—or even perhaps hurtful effects.

I will frankly acknowledge, that I myleft, was fo far impofed upon by the beauty of this theory, as to be hurried along with the general current of mankind, in the firm perfuation of the truth of this obfervation, and for many years did not fufficiently advert to thole facts that were daily occurring to contradict this theory. I am now, however, firmly convinced, from repeated obfervations, that lime and other calcareous manures, produce a much greater properional improvement upon poor foils, than on fuch as are richer : And that lime alone, upon a poor foil, will, in many cafes, produce a much greater and more lafting degree of fertility, than dung alone.

In direct contradiction to the theory, I muft add, that I never yet met with a poor foil in its natural flate, which was not benefitted in a very great degree by calcareous matters, when adminiftered in proper quantities. But I have met with feveral rich foils, that were fully impregnated with dung, and therefore exactly in that flate in which the theory fuppofes that lime would produce the greatefl effect; but, upon which, lime, applied in any quantities, produced not the fmallet femible effect.

As I concern myfelf little about theories, this difcovery gave me much lefs uneafinefs than it will give to fome of my readers; on which account, I finall not be much furprifed, if they withhold their affent to this propolition for a very long time. I do not defire any one

AS A MANURE.

I fhall conclude this very long Edlay with a cautionary advice, that might, perhaps, have been more properly introduced before, if it had occurred at the time ; but it is of too much importance to be omitted entirely. It is this :

When farmers employ a great deal of lime, it fometimes happens that their horfes' feet are burnt by it, which is extremely troublefome, and fometimes proves even fatal to the poor animals*; a method of preventing or remedying that inconvenience will therefore be of ufe.

The beft method of preventing any inconvenience of this fort, is to fpread the lime, when in its powdery flate, upon the field, as evenly as poffible, and allow it to lie in that flate for fome time, before you begin to plough it. If the lime has been in fine powder, it will have become perfectly *effette* in a week or fo; after which time it will be as little corrofive as any kind of common earth, fo that the horfes may work among it with perfect fafety. But if it has been fufficed to ruu into clods before it was foread, thefe, if not broken fmall, will be longer in abforbing their air, and, of confequence, will remain longer in an acrid ftate, fo that the ploughing may, in that cafe, be deferred for a week or fo longer; nor will it be even then fo perfectly fafe as the other.

But if it becomes neceffary at any time to plough in the lime immediately after it is fpread,—take care to do it only when the foil is perfectly dry; and in leading

* I have known feveral horfes actually killed by this means, and others fo difabled as never to be perfectly well afterwards, ing your horfes to the plough, take care to prevent them from going through any wet place, fo as to wet their hoofs or ankles; for line acks not at all upou any dry fubliance,—but when it is in its acrid cauftic flate, it would corrode the hair and fiefh in a moment, if it has accefs to water. As foon as the horfes are unyoked, keep their feet dry till you have got them carefully bruthed, fo as to wipe away all the dry powdery lime that may adhere to them; and if the leaft flower thould fail, unyoke your horfes immediately and carry them off the held.

With these precautions, they may work among caustic lime for any length of time, without receiving any damage.

But in cafe of any accident, by which a lorfe or man that is working among line thould be fcalded by it, it is always advifable for every farmer who has work of that kind going forward, to keep a tub of very four milk or whey in fome place ready to wath the part affected well with it, which will quickly deftroy the pojgnancy of the lime, and prevent the mifchief that would otherwife arife from it. The forere the milk or whey is, the better it will be for this parpofe; it ought therefore to be long kept. For want of this, vinegar will produce the fame effect, or very the cheapeft and beft remedy, and ought to be always in readinefs.

POSTSCRIPT.

AS A MANURE.

POSTSCRIPT.

Directions for afcertaining the purity of Lime, and difeouering the Nature of the Bodies that may be mixed with it.

§ I.

In the preceding Effay, I have fupposed that no other abforbent* earth is ever mixed with the calcareous in any fort of lime-ftone ; because, in fact, if ever any of thefe are mixed with the calcareous in thefe fubftances, they are in fuch fmall proportion as not to be worth regarding. Thofe, however, who want to be critically exact in their analysis of lime-ftone, may difcover if there is any other fort of abforbent earth contained in it, by dropping into the filtred folution obtained by the process § 13, p. 72, a few drops of a clear folution of volatile alkali. If no turbidness enfue, the calcareous earth has been pure. If any precipitation takes place on adding the alkali, drop more, and more, till no turbidnefs arifes : then filtre the whole : what remains in the filtre, is abforbent earth, that is not calcareous ; for acids attract volatile alkali more flrongly than any of the abforbent earths, except the calcareous class alone

\$2.

It may oftener happen, that a confiderable proportion of gp/lum may be united with lime-tone in the fame quarry; and as this fubflance would greatly alter the nature of the lime as a cement (fee p. 37) and would probably affect it as much as a manure, it is of more importance to inform the reader of the eafield way of difcovering this fubflance when it is prefent in limefone. It

* Abforbent earths are all those that unite with acids, of which there are feveral varieties; calcareous earths being one of these. It has been already [aid, that gyp/um is a compound, confifting of the vitriolic acid and calcareous earth ; and as the vitriolic acid attracks this earth more frongly than any of the other acids, this composition is not in the leaft affected by either the nitrous or muriatic acids.

Hence it follows, that if gypfum thall be contained in any calcareous mafs examined by the process defcribed § 13, p. 72, it will remain untouched by the acid, and be found in the filtre, after the calcareous earth diifolved in the acid fhall have patied through it, forming a part of the *r*(fduum.

Take this refiduum, therefore,—add to it nearly its weight of fixed alkali* previoully diffolved in a confiderable quantity of water, and filtered; diget it in a warm bath, or even boil it for fome hours; pour the whole into a filtre, while yet warm; a sche fluid paffes through the filtre, pour upon it more boiling water; as that paffes off, continue to add more water, till it comes through the filtre quite infipid and pure, and then let it run off entirely.

By this procefs, the viriolic acid leaves the calcareous earth to unite with the fixed alkali (to which it has a flronger affinity) and with it forms a viriolated tartar: — this vitriolated tartar, and the fuperfluous alkali, are diffolved by the water, and carried through the filtre along with it; fo that what remains behind is the earthy part of the gyp/um, and the heterogeneous matters contained in the original line-flone. By pouring upon this refiduum, therefore, fome nitrous or muriatic acid, and treating it as directed in § 13, page 72, the calcareous earth that was in the gyfum will be now entirely diffolved; fo that when it is filtered and dry, the difference between the weight of this refiduum, and what it formerly was, is the real weight of the gyfum originally contained in the lime-flone.

N. B.

* Potafh,

N. B. If the alkali employed to decompose the gypfum was in a mild flate, the calcareous earth that remains will effervece (trongly when it is dillolving in the acid; but if a *cauftic* alkali has been employed, the folution will be effected without any efferve/cence at all.

As vitriolated tartar is not readily foluble in water, a confiderable quantity of water requires to be employed, which ought always to be hot, that the folution may be effected the more readily.

It has also been faid, (§ 30, p. 52,) that the only extraneous matter contained in lime-itone is fand. But although fand, in general does predominate to much over the other extraneous matters in lime-flone, as to authorite the expredition in general, yet there are fone exceptions that ought to be taken notice of.

1/å, There are fome kinds of lime-flone, that, when analyfed, are found to contain a *refiduam* confiiting of a foft iliny like fubflance. This is always in very fmall proportions, and has probably been formed by a fediment fubfiding from the water while the rock was forming. It feems probable, that this kind of lime would be lefs proper to be employed as a cement than as a manure.

2d. Although marle and lime-flone are juftly enough diffinguished in the text ($\S = 5$;) yet it happens, that elay and fand are found naturally mixed with one another, in fuch various proportions, and in the fates joined with calcarcous matter, that there is no poffibility of afcertaining the exact point where marle ends, and lime-flone begins.

A very fmall proportion of clay is fufficient to make an exceedingly hard lime-flone relent in time in the air, and fall to pieces; fo that there are many forts of flone marle that confift chiefly of faud and calcarous earth, and only a very little clay.

Thefe

Thefe very hard kinds of marle may be eafily burnt into lime, fo that they may be indifferently called marle or lime-ftone.

3.4. The fame may be faid of the diffindion between mark and chalk (§ 5. p. 9.) Many fubliances which have the appearance and diffinguithing properties of chalk, contain clay in different proportions. The for the air, or raw, as it is remed, more readily than the pure hard kinds of chalk, and feel more unctuous or fatty to the touch; from whence they are called fat chalks. Thefe, however, may be converted into lime; fo that they might indifferently be called *chalk*, mark, or lime-flow.

The lime that is made from any of thofe fubflances that contain clay in their composition, is more proper for manure than for coment; effectally that made from thole fubflances that may be made to *fall* after they have undergone only a finall degree of heat in calcining them, as in *cheik*; becaufe, in thefe cafes, the clay will not be fufficiently burnt to prevent it from being affected by water, and rendered for by it.

The proportion of clay and fand contained in any lime flome or marke, may be afcertained, by diffuling in water the *rofiduum* obtained by the analylis, $\S_{1,25}$ p, 72³) allowing it to fublide a little, and gently pouring off the fluid parts from the coarter fediment that fubfides to the bottom ; for, as clay remains much longer fupended in water than fand, it may be thus feparated from the fand entirely ;—when the water comes off clear, after baving been left to fubfide a litite, the *rofiduum* may be evaporated to drynefs, and the loss of weight it has fullkined by this operation, denotes the duality of clay.

This is rather a mechanical, than a chemical procefs, which is called *elutriation*. § 4.

* Obferve, it is unburnt lime-flone, or marle only, that flould be fubjected to this trial.

It has been demonfirated above, § 35, p. 58, that the quality of lime, confidered as a cement, is greatly altered, by being more or lefs perfectly calcined ;it may therefore be, on many occafions, of ufe to thofe who are concerned in building, to be able to effect and what proportion of any particular kind of lime is really reduced to a cauftic flate.—This may be done as under :

Take a known quantity of the quick-line, perfeelly dry-add to that its own weight, or more, of common crude fal-ammoniae," previoufly diffolved in a large proportion of water, and filtered ;--digeft this nearly in a boiling heat for fome hours, till no more finell of volatile alkali is found to arife from it, adding freh water as it evaporates. When the volatile alkaline fmell is no longer perceived, throw the whole into a filter,--the that pafs cff_-add more hot water,--and more fill, till it come through the filtre tafklefs and pure ;--then dry the *rofolaum*, and weigh it;--the difference between that and the weight of the original line, denotes the proportion of pure cauffic line that was containe to in the original mais.

For, as the mutuate acid attracts carefic calcarcents earth more fitningly than it does the volatile atkali, the acid of the fal-ammoniac, t during the precefs, quits the alkali, and usites with the line, and the alkali is furfered to fly off in a pungent vapour. The new fubflance formed by the union of the quick-line with the mutuatic acid, is called *liquid fhell* ; and as this is readily folloble in water; it paffes off, together with the remaining undecompofed ammoniacal fait, with the water through the filter; while the uncauffic line, as it was neither capable of acting upon the ammoniac, nor of being diffolved in the water, remains behind in its folid itae.

* Obferve, it is not volatile fal-ammoniac.

† Crude fal-ammoniac is a compound fait, confiling of the muriatic acid and the volatile alkali.



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II.

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• of Enclera, the Monthly Reviewer: Jaid in March, 1796, • The annual of time do not, berhapi, contaits a name more reeveral, by the beft and wielf friends of the human vices, than that of Enclons, and it is to be aborbed, whether any production of human genics view was lo efficient in englishening mankind, and in vendering them benesolent and julf, as the beautiful philosphic power of Teleman... It contains a greater portion of political and moral wildow, than, as we believe, is to be fund in any preceding work."

12.

The fame work is to be had in English, with the French text on the opposite page, with corrections, in two vols. 12mo.

13.

Alfo in French, feparate .- For execution and accuracy, the above is fuperior to the late English edition.







