

DAMAGE CAUSED BY SALT

AT KARNAK

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Attention has often been called to the destructive action of salt on the buildings and other monuments at Karnak and the present Director of Works, M. M. Pillet, has made special mention of this in his annual reports for several years past.

At the request of M. Pillet the writer recently (March 1925) had an opportunity of examining Karnak and of taking for chemical analysis specimens both of the disintegrating stones and of the efflorescent salts. The following report gives a brief account of the observations made and of the results of the analyses, together with a few suggestions of the means to be adopted to diminish the salts and to lessen the damage.

NATURE AND EXTENT OF DAMAGE. — The upper portions of the buildings and monuments are free from any particular surface disintegration and also from any signs of damp or of efflorescent salts.

The damage is confined to two areas, namely *a*) an irregular zone some distance up the walls, which marks the height to which at one time earth has been piled, and which is often well above the highest level to which any water can have risen by capillarity, and which in many cases is marked by a broad band of damp, and *b*) a zone extending from the floor level to a height varying from about half a metre to several metres above and where there is generally a white incrustation. But both damp and incrustation, although very unsightly, are merely the outward manifestations of the presence of the powerful destructive agent salt, which is insidiously ruining the stone, beginning with a disintegration of the

surface and frequently ending with total destruction. The damage is very considerable and needs to be seen to be fully realized, the surface of the lower parts of the walls and monuments in many cases having entirely disappeared often to a depth of five millimetres but sometimes to a considerably greater depth. This naturally has not only destroyed the inscriptions but is also a source of weakness to the stone. In other instances individual stones are in a state of complete disintegration and fall to pieces when touched. This damage, which has been taking place for many years, is still actively going on at the present time and is common alike to sandstone, granite, limestone and alabaster.

Before any remedy for the present disastrous condition of things can be considered, it is necessary to know the nature of the salt, the manner in which it acts and more particularly how it has originated and accumulated. These points will now be dealt with.

NATURE OF SALT. — The salt consists largely of sodium chloride (common salt) and is generally a mixture of sodium chloride and sodium sulphate with occasionally small proportions of other salts, such as sodium carbonate and sodium or potassium nitrate and, in those places which remain permanently damp, a deliquescent material, probably calcium chloride.

ACTION OF SALT. — The action of salt on stone is not analogous to its action on metal and as a rule is little, if at all, chemical, but largely physical and is caused by the salt crystallizing underneath the surface layers of the stone, which are pressed off by the irresistible force consequent on the growth of the crystals.

ORIGIN OF SALT. — Unless the origin of the salt is clearly understood mistakes will be made with regard to any remedies suggested. It is not sufficient to state in a loose way that the salt comes from the ground or is brought by the infiltration water that annually floods the temple area, but it must be known exactly how the salt comes to be in the ground and from where it is brought by the water.

In this connection two cases, which at first sight might seem to be

parallel, but which in reality are very different, may be mentioned. These are Luxor temple and Philæ temples. At Luxor the temple, which is built of similar material to Karnak and which stands much closer to the river than Karnak, was at one time piled up with earth, rubbish and mud brick houses as at Karnak and is annually flooded in the same way as at Karnak and yet there is practically no evidence of salt. What is the reason for the difference? At Philæ, with the soil of the island full of salt until a few years ago, there are temples built of similar material to those of Karnak, annually submerged for several months each year and, although slight damage was caused by salt in the early stages of the flooding when the Aswan dam was first built and although there is still slight damage to the tops of the few buildings that are never entirely submerged, yet Philæ is free from the danger that is destroying Karnak. Why is this?

At Luxor, which is situated on the Nile bank, water finds its way into the temple each year at the time of the annual flood. This river water is particularly free from salt and it has such a short distance to travel to reach the temple that it cannot pick up more than a very slight amount, if any, of additional salt in its passage. At Luxor also there is free and quick drainage of the water back to the river when the flood subsides and therefore the water drains away before it has time to evaporate and deposit even the slight amount of salt it contains and, on account of the good drainage, the general level of the subsoil water is low. Hence at Luxor there is no constant addition of fresh salt and even during the time that the temple area was crowded with houses there could not have been any great accumulation of salt in the subsoil or foundations on account of the annual flooding with fresh water and the subsequent quick and complete drainage, but on the contrary there was probably a washing out of some of the salt already present.

At Philæ, although the buildings became infected with salt derived from the soil of the island when the level of the river was first artificially raised, this salt has since largely been washed out again by the annual submergence and salt now only remains in small amount in those parts of the buildings that are still above the highest water level and it would be better if these also could be submerged.

At Karnak the conditions, although at first sight much the same as those at Luxor and Philæ, are in reality very different. The water flooding Karnak although Nile water does not come directly from the river, but is water that has irrigated and washed the land to the south and east before it reaches the temple area, and as a result it must pick up a certain amount of salt in its passage. After remaining for a short time the water subsides but, as the drainage conditions are very poor, although much of the water slowly finds its way back to the river a portion remains in the subsoil and a further portion drains into the depression on the south side of the temples where it forms the sacred lake. Before the infiltration water subsides there is a certain amount of evaporation with consequent increase in the salinity of what remains: in the lake too there is also evaporation of the water and concentration of the salt. This process has been going on for several thousand years with the result that salt has gradually accumulated in both the subsoil water and in the lake water. In addition to this however salt in large quantity was undoubtedly derived from the urine of the human and animal inhabitants of the temple area during the time it was encumbered with houses and rubbish heaps and used as a dwelling place for a large colony of people. Under the imperfect drainage conditions that exist the accumulated salt from this source would never have an opportunity to escape but remained in the temple area and at the present time the soil, the subsoil, the subsoil water, the lake water and the foundations and lower courses of the buildings are all impregnated with salt.

REMEDIES. — Since the damage is caused by salt and since salt is harmless when quite dry the obvious remedy, if possible, is to remove either the salt or the water. These possibilities will now be considered.

SALT. — Salt is present in large amount in the subsoil water, in the lake water, in the subsoil, in the soil, in the foundations of the buildings and in the stonework of the buildings. These may be considered separately.

SALT IN SUBSOIL WATER AND IN LAKE WATER. — The subsoil water and the lake water are two of the great sources of the salt that is causing the

damage. This salt can only be removed by removing the water, that is by lowering the present minimum level of the subsoil water and by draining the lake. In what manner this could be done without endangering the foundations of the buildings is a problem for the engineer. Any general improvement of the drainage of the area however would act in the required direction.

SALT IN THE SOIL, IN THE SUBSOIL AND IN THE FOUNDATIONS. — These are other great sources of the salt that is causing the damage. The salt in the soil, subsoil and foundations can only be removed by washing it out. One way of doing this would be to flood the whole of the temple area from the surface downwards with sweet (river) water during the period when the level of the subsoil water is at its lowest and hence when the water could drain away best. The natural drainage however might have to be supplemented. A similar result would be attained by the natural flooding of the area by infiltration water, as at present, if the level of the subsoil water could first be lowered and the salty lake water removed.

SALT IN THE STONWORK. — This salt is the cause of the unsightly damp patches and white efflorescence on the walls and has already destroyed many of the inscriptions and is endangering more; it is fed from the various sources enumerated above. Suggestions for dealing with this will be given later.

WATER. — As already mentioned, the water entering the temple area is that which filters through from the irrigated land situated to the south and east of Karnak. The problem of preventing the annual flooding of the temple by this infiltration water has been the subject of considerable study from time to time and several reports on the matter have been made, one of very recent date. As the problem is almost entirely non-chemical and therefore largely outside the writer's province it will not be discussed though a few special points involving chemistry may be mentioned. These are :

1. If the salty water in the subsoil and in the lake could be removed or even reduced in volume and if the salt in the soil, subsoil and foundations could be largely washed out, any infiltration water would contain

very much less salt than it does at present (since it is from these sources that the salt is largely derived) and therefore the natural annual flooding would cause very little damage, as is proved for example at Luxor⁽¹⁾.

2. Any improvement in the drainage conditions of the temple area would tend to prevent further accumulations of salt.

3. The mere prevention of a visible flooding of the temples while an underground flooding still continued would be of very little benefit so far as the salt menace is concerned, unless the level of the subsoil water under the whole area could be kept permanently so low that the water (which carries the salt with it) could not rise by capillarity to the ground level.

SALT IN THE STONEWORK. — This has already been referred to, but will now be considered in detail. It has been stated that salt if dry causes no damage and therefore it might seem that once having got rid of the infiltration water the salt in the stonework need cause no uneasiness. But this salt is very unsightly and for this reason alone it would be desirable to remove it. Also, it is impossible to keep the salt permanently dry, since there is often considerable moisture in the air and even occasional rain, and salt absorbs moisture readily from a damp atmosphere. It would be better and safer therefore to remove the salt. But any measure of this kind would be useless until the problems of infiltration water and salt in the subsoil and foundations have been dealt with, since if the salt now disfiguring and destroying the stonework were removed without any amelioration of the other conditions it would gradually return again and soon would be as bad as ever. No attempt therefore should be made to remove the salt from the stonework above ground level until the larger and more fundamental problems have been solved. When the underground reservoir of salt has been satisfactorily closed, but not until then, the salt above ground may be considered. In the hope that such a time is not far distant a few suggestions for the treatment of the stonework will be given.

⁽¹⁾ Apart from danger due to the rise and fall of the water level and of any washing away of fine material from the foundations.

1. By the judicious use of dry brushes and scraping, especially in those places where there are no inscriptions, a large amount of salt may be removed. This work however is of a very delicate nature and should be entrusted only to trained and competent men.

2. By the repeated applications of soft cloths soaked in hot water to those places where there are efflorescences of salt much could be removed. The water employed must be sweet (river) water and not well water as this latter is often very salty and the cloths should be thoroughly rinsed in sweet water between each application. This also is work only to be undertaken by trained and competent men.

Both the above-mentioned methods would have to be repeated from time to time but gradually the greater part of the salt would be removed permanently.

MISCELLANEOUS. — There are several points of a miscellaneous nature that may be mentioned. These are as follows :

1. The writer has not seen Karnak during or immediately after the period of infiltration and therefore is unable to say whether algæ occur or not, though this is very likely, since they do occur at Philæ, but if algæ from the water cling to the walls when the water subsides they cause no damage but quickly die and dry up.

2. The writer cannot find evidence of any destruction of the stone at Karnak being caused by fungus growths.

3. The water employed for making mortar or for any other purpose in connection with restoration work should always be river and never well water.

4. Any rebuilding, if starting from ground level, should include a damp course of bitumen.

5. All loose blocks of stone placed on the ground to await until they can be dealt with should be so placed that the side bearing the inscription is at the bottom as salt always mounts to the upper surface of a stone. Such blocks too should be raised on supports above the ground as is now being done.

6. Each year after the subsidence of the infiltration water any efflorescence on the ground should be scraped off, as has already been occasionally done, and the scrapings should be thrown into the river and not dumped in the immediate vicinity of the temples nor thrown into the lake.

7. In places where an inscription is badly damaged and is in danger of disappearing through the surface layers of the stone flaking off this may be consolidated and preserved by impregnating it with a dilute solution of celluloid dissolved in amyl acetate. Several applications of the solution will be necessary and the first should be about 0.5 per cent. strength and should be followed by a slightly stronger solution, about 1 to 2 per cent strength. The solution is best applied by means of a small spraying apparatus but may be used with a small brush. The stone must be quite dry before treatment.

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