MINISTRY OF FINANCE, EGYPT.

SURVEY DEPARTMENT.

THE METEORITE OF EL NAKHLA EL BAHARIA,

BY

JOHN BALL, Ph.D., D.Sc., F.G.S.

SURVEY DEPARTMENT PAPER, No. 25.

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CONTENTS.

Plates.

THE

METEORITE OF EL NAKHLA EL BAHARIA.

1.—Introduction.

On the 28th June, 1911, at about nine o'clock in the forenoon, a number of meteoric stones fell to earth in the hamlets surrounding the village of El Nakhla el Baharia (31° 19′ N., 30° 21′ E.), in the markaz (police-district) of Abu Hommos, in the north-western portion of the Nile Delta of Lower Egypt. (*See* Map on Plate I).

The locality where the fall occurred is inhabited chiefly by uneducated peasants, and the meteorite would probably have been lost to science but for the action of a farmer, Mohammed Ali Effendi Hakim, who communicated a note of the occurrence to the Arabic newspaper "El Ahali." It was found on subsequent enquiry that the place and date given in the newspaper account were not quite correct,* but the notice was instrumental in leading to investigations by which the fact that a fall of meteoric stones had really taken place, and the circumstances attending it, were ultimately ascertained.

Enquiries by the Geological Survey led to specimens of the stones being procured from the peasants by the Ministry of the Interior, and when it was evident from these that there could be no doubt as to the meteoric origin of the stones, Dr. Hume, the Director of the Geological Survey, personally visited the district and collected both the evidence of eye-witnesses of the fall and about a dozen specimens, including the largest known fragment. Later on, another fine fragment was collected by Mr. Brigstock, of the Agricultural Department. As it was considered likely from this further find that still more specimens

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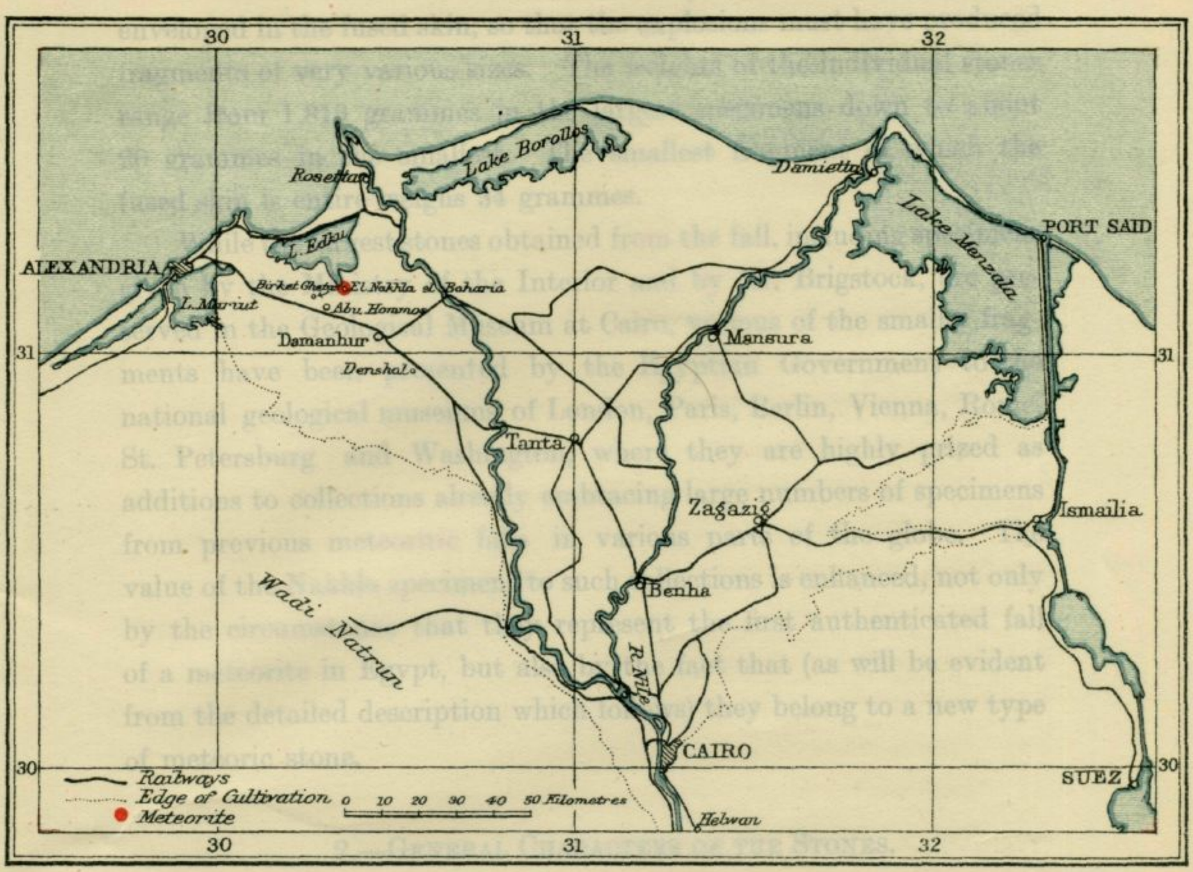
* The newspaper account gave the place of the fall as Denshal, which is about 33 kilometres south-east of El Nakhla el Baharia, and the date as June 29th. Careful enquiries at Denshal showed that no meteorites had fallen there, nor had the smoke-column been seen. The statement in the newspaper that one of the stones fell on a dog at Denshal, "leaving it like ashes in a moment," is doubtless the product of a lively imagination.

of the stones might be in the hands of the peasants, Dahab Effendi Hassan, of the Geological Survey, was sent to the place in October, and succeeded in purchasing no less than twenty more of the stones, which in his opinion are all that were in the hands of the peasants at the time.

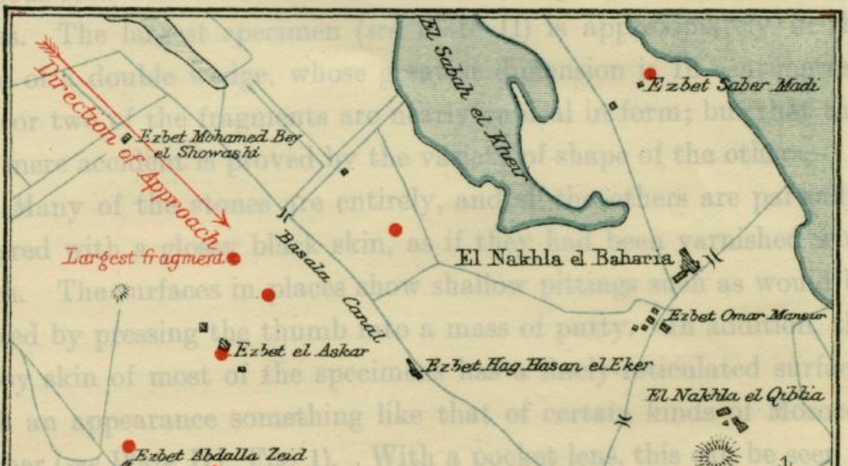
From the evidence of eye-witnesses, most of whom were peasants who had been working in their fields, it appears that the stones fell over an area about 4½ kilometres in diameter, and were derived from the explosion of a single large meteorite at a considerable altitude in the air. The direction of approach of the object was from the north-west, and its track, marked by a column of white smoke, is said to have been inclined only some 30° to the horizontal. The explosion appears not to have been a single one, but to have been several times repeated, with a loud noise variously likened to the firing of a gun and to the pulling-up of a railway train at a station. The column of smoke is said to have been seen, and the sound of the explosion heard, near the village of Birket Ghetas, which is some seven kilometres from the centre of the area where the stones fell. Curiously enough, a peasant who saw a stone fall about fifty metres from him near Ezbet Saber, on the opposite side of the centre of the fall to Birket Ghetas, did not remark any sound of the explosion, but only noticed a cloud of dust where the stone struck the earth. The stones buried themselves to depths of from ten to thirty centimetres in the ground, and are stated to have been cool when dug out. The holes showed an inclined course, not a vertical one.

Altogether about forty stones, of a total weight of nearly 10 kilogrammes, were collected. Of these, about half are completely enveloped in a black varnish-like skin of fused matter. Some have one or more of their faces only partially fused, while others exhibit fresh fractures showing the greenish-grey crystalline interior. The various degrees of fusion noticeable corroborate the statement that there were several explosions, the partially fused surfaces being evidently the result of the later fractures, while the unfused faces are doubtless in some cases due to breaking up of the stones after striking the earth. Some of the smallest of the stones, as well as the largest, are completely

SKETCH-MAP OF LOWER EGYPT
SHOWING THE POSITION OF EL NAKHLA EL BAHARIA.



LARGE-SCALE MAP OF EL NAKHLA EL BAHARIA DISTRICT,
SHOWING THE PLACES WHERE THE PRINCIPAL METEORITE-FRAGMENTS WERE FOUND.



Survey Dept. Cairo 1911. 87-190

enveloped in the fused skin, so that the explosions must have produced fragments of very various sizes. The weights of the individual stones range from 1,813 grammes in the largest specimens down to about 20 grammes in the smallest. The smallest fragment of which the fused skin is entire weighs 34 grammes.

While the largest stones obtained from the fall, including specimens given by the Ministry of the Interior and by Mr. Brigstock, are preserved in the Geological Museum at Cairo, various of the smaller fragments have been presented by the Egyptian Government to the national geological museums of London, Paris, Berlin, Vienna, Rome, St. Petersburg and Washington, where they are highly prized as additions to collections already embracing large numbers of specimens from previous meteoritic falls in various parts of the globe. The value of the Nakhla specimens to such collections is enhanced, not only by the circumstance that they represent the first authenticated fall of a meteorite in Egypt, but also by the fact that (as will be evident from the detailed description which follows) they belong to a new type of meteoric stone.

2.—General Characters of the Stones.

In form, the stones are mostly sub-angular, that is, they are of shapes such as one would obtain by breaking up a big mass of homogeneous rock with a hammer and then very slightly rounding off sharp edges. The largest specimen (*see* Plate II) is approximately in the form of a double wedge, whose greatest dimension is 16 centimetres. One or two of the fragments are nearly cubical in form; but that this is a mere accident is proved by the variety of shape of the others.

Many of the stones are entirely, and all the others are partially, covered with a glossy black skin, as if they had been varnished with pitch. The surfaces in places show shallow pittings such as would be caused by pressing the thumb into a mass of putty. In addition, the glossy skin of most of the specimens has a finely-reticulated surface, with an appearance something like that of certain kinds of Morocco leather (*see* Plate III, Fig. 1). With a pocket lens, this can be seen to

*

be due to a fine network of tiny anastomosing ridges, separated by little pits; the ridges appear to be the traces of the surfaces of separation of the grains composing the stone, while the pits mark the central portions of the grains.

Where only incipient fusion has occurred, as in the case of surfaces fractured shortly before striking the earth, the melting of the stone has been selective, certain grains being fused and others not, showing that the meteorite consists of at least two minerals of different degrees of fusibility.

On freshly-fractured surfaces (*see* Plate III, Fig. 2) the rock is of a greenish-grey colour, fine-grained and crystalline. Examination with a pocket lens reveals a mixture of reddish-brown and pale-green minerals, mostly in shining crystals, but partly in a dull form in which the green matter takes on a whitish aspect.

On comparing a fresh fracture with a surface showing incipient fusion, it is evident that the brown mineral (hypersthene) is the more easily fusible one, being converted into a black glass while the green crystals (augite) are scarcely affected.

Except where protected by its black crust, the stone is very friable, and can often be crushed into a crystalline powder between the finger and thumb, like a piece of bad mortar.

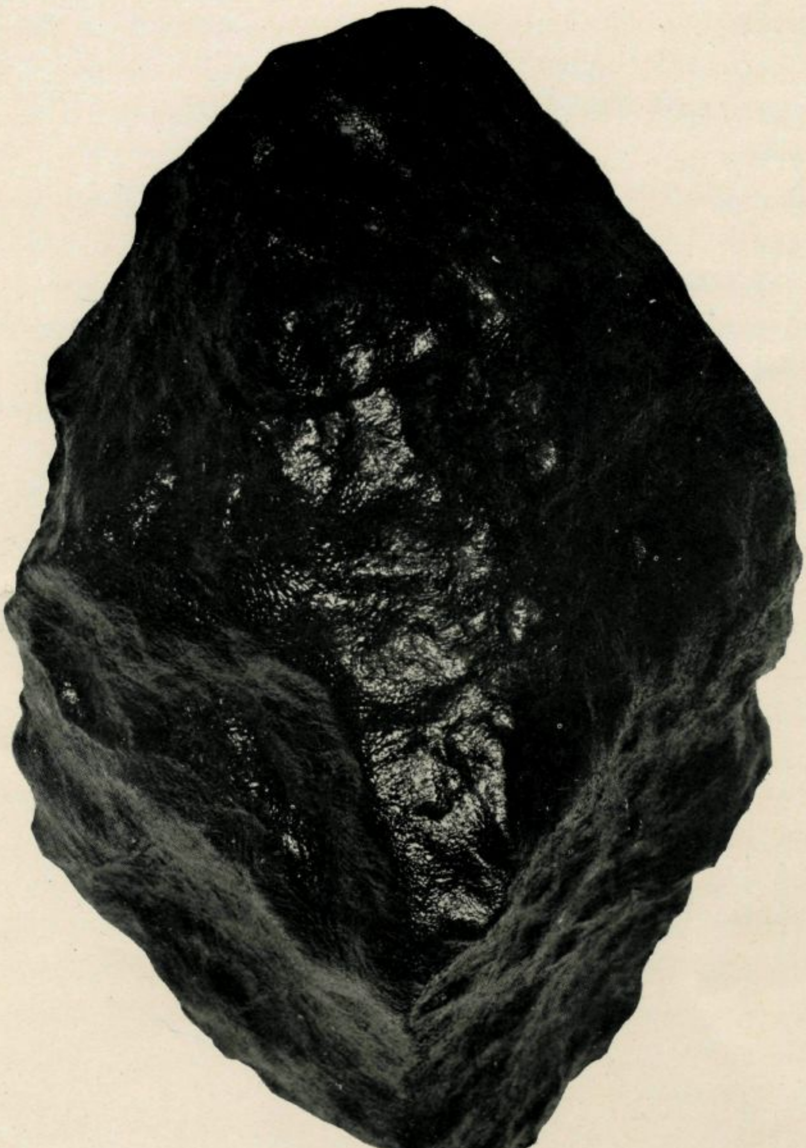
There is no trace of the chondrules so common in stony meteorites, the texture of the rock being remarkably uniform.

Metallic iron and nickel, too, are entirely absent. When a magnet is applied to a powdered specimen of the stone, only a few grains are attracted, and these appear to be oxides rather than metallic iron.

The specific gravity of the stone is 3·40.

3.—Petrographical Characters of the Stones.

For the investigation of the mineralogical composition of the meteorite, I had two large thin slices cut from the specimen presented by Mr. Brigstock, and submitted them to microscopical examination. The slides show the stone to be a holocrystalline aggregate of augite and hypersthene, in which the grains have an average diameter of about half a millimetre (*see* Plate III, Fig. 3).



The largest fragment.
(natural size.)

The augite, which forms about three-quarters of the stone, is nearly colourless in thin section, showing only a faint greenish-brown tinge. The crystals, though mostly allotriomorphic, frequently show a strong tendency to idiomorphism in the usual prismatic habit. Prismatic cleavage is very strongly marked, both in vertical and basal sections, and the crystals show in addition numerous large irregular cracks. Many of the crystals are of a clouded aspect, which under a high power is seen to be largely due to abundance of small irregular cracks. The refractive index and double refraction are both high. The extinction-angles in prismatic sections measure up to 43°. In sections parallel to the clinopinacoid, where the extinction-angle is a maximum, twinning parallel to the orthopinacoid is frequently seen, a number of twin-lamellae usually running down the centre of the compound crystal. In basal sections both twinning and extinction are of course diagonal to the cleavages. Some clinopinacoidal sections show a herring-bone structure under crossed nicols, due to extremely fine lamellation parallel to the basal planes, which in the twinned crystal are inclined at an angle of about 75° on either side of the vertical.* These lamellations and the traces of the vertical twinning planes can be distinctly made out even in ordinary light, but they are more conspicuous when the section is viewed between the nicols.

The hypersthene, forming the remaining quarter of the stone, is mostly in rounded grains, usually larger than those of the augite. It is nearly colourless in thin section, having even a fainter greenish-brown tinge than the augite, and does not show distinct pleochroism. Cleavage is not very strongly marked, but wherever it can be seen the crystals show straight extinction. Irregular cracking is very pronounced, and frequently there is a yellowish-brown staining of the crystal evidently by iron oxide, along and near the cracks. Almost all the hypersthene crystals contain numerous minute opaque enclosures, which are usually lenticular in shape and are arranged in lines perpendicular to the principal cleavage. The refractive index and the

* A similar structure is found in the augite of the Whin Sill of Tyne Head (TEALL, *British Petrography*, p. 208) and other terrestrial rocks.

double refraction are both higher than those of the augite. The double refraction is thus much stronger than is usual in hypersthene, the colours of the third order being sometimes reached. The absence of pleochroism and the brilliance of the polarization colours give the crystals a strong resemblance to olivine in thin section, and in fact until the chemical investigation was made no hesitation was felt in regarding the mineral as olivine. But as the chemical analysis (*see* p. 9) proved conclusively that the proportion of bases to silica in the whole meteorite was (like that in augite) practically 1 to 1, it was impossible that any appreciable quantity of olivine (in which the ratio of bases to silica is 2 to 1) was present in the rock. Subsequent tests with the quartz wedge showed that the crystals which had been at first taken for olivine had the optic orientation $\mathfrak{c} = c$, so that there could be no doubt of the mineral being a rhombic pyroxene. The abundance of systematically-arranged opaque enclosures is of course much more characteristic of a ferriferous rhombic pyroxene than of olivine, and these and the high content in iron (the mineral has a composition approximately $2FeSiO_3$, $MgSiO_3$) prove it to be hypersthene. The large proportion of iron probably explains the phenomenally high double refraction, as it is well known that this latter increases with an increase in the iron-content; the absence of colour and pleochroism is less easily explainable, as the separation of iron-oxides in the schiller-structures and along cracks hardly looks sufficient to account for such a thorough bleaching.

Felspars are entirely absent, the accessory minerals in the stone comprising only a few scattered small grains of chromite, and here and there interstitial wisps, sometimes in little radiating aggregates, of a rather clouded fibrous-looking brown to colourless mineral of very low refractive index and polarising in low colours. I have not been able to make sure what this last-mentioned mineral is, but am inclined to think that it belongs to the chlorite group. Both the iron oxides and the doubtful mineral just mentioned are present in very small quantity, probably both together representing about one per cent of the entire stone.

The mineralogical composition of the meteorite, which is prac-

FIG. 1. Exterior view of the specimen collected by Mr. Brigstock, showing the reticulated surface.

(Natural size).

FIG. 2. Fractured surface of the same stone, showing its crystalline structure.

(Natural size).

FIG. 3. Thin section of meteorite, magnified 20 diameters. The upper three-fourths of the figure show augite-crystals in basal and prismatic section. At the top of the field, a twinned augite-crystal showing herring-bone structure. At the bottom of the figure, part of a large crystal of hypersthene, containing opaque inclusions.

tically three-fourths augite and one-fourth hypersthene, is in good agreement with the specific gravity of 3·40 found by direct measurement, augite having an average specific gravity of 3·3 and hypersthene one of 3·5.

4.—CHEMICAL COMPOSITION.

A spectroscopic examination of the meteorite, kindly carried out at South Kensington by Sir Norman Lockyer at Dr. Hume's request, showed the lines of the following elements to be represented :—

Element.	Intensity of Lines in Spectrum.
Chromium	Very strong.
Sodium	" "
Calcium	Strong
Aluminium	"
Magnesium	Fairly strong.
Silicon	" "
Manganese	"
Iron	" "
Vanadium	Rather weak.
Titanium	" "
Potassium	Slightest trace.

Sir Norman Lockyer remarks that the most distinguishing feature in the spectrum of this, as of nearly all other stony meteorites, is the conspicuousness of the chromium lines.

A chemical analysis of the meteorite has been made by Mr. W. B. Pollard in the chemical laboratories of the Survey Department. The quantitative analysis was confined to the determination of those constituents which a preliminary examination had shown to be present in appreciable quantity, so that although the analysis was carried out with all the detailed care and special precautions necessary for accurate rock-work, it does not claim to be an absolutely complete one. The results are :—

	Per cent.
SiO_2	49·98
FeO	19·58
CaO	15·12
MgO	12·20
Al_2O_3	1·65
Cr_2O_3	0·23
H_2O	0·35
	99·11

In addition to the constituents mentioned above, distinct traces of MnO, TiO_2, and V_2O_3 were found; these are all included in the Al_2O_3 in the analysis. All the iron was estimated as FeO, though probably a very small portion of it is present as Fe_2O_3. Sodium was found to be present in the chemical analysis, but was not estimated; since the other constituents add up to over 99 per cent, the amount of Na_2O cannot be large. Potassium, though indicated by the spectroscopic test, was not detected in the analysis, and can only be present in the merest traces.

In deducing the ratio of basic to acid molecules in the stone from the above analysis, we must remember that the microscopic examination revealed the presence of small amounts of bases in the free state, namely, iron and chromium oxides in the chromite and in opaque inclusions in the rhombic pyroxene. To counterbalance this, we may for a first approximation neglect the small percentage (1·65) of Al_2O_3 shown by the analysis; so heavy a molecule as Al_2O_3 can take up only a small proportion by weight of silica, and we may fairly assume that in regarding the Al_2O_3 and Cr_2O_3 as free, and all the iron as combined in the form of FeO, we are retaining very closely the actual ratios of bases to acids. Taking the remaining principal constituents, we have:—

	Percentage in Rock.	Molecular Weight.	Molecular Proportions.	
SiO_2	49·98	60·4	0·828	0·828
FeO	19·58	72	0·272	0·845
CaO	15·12	56	0·270	
MgO	12·20	40·3	0·303	

It is thus clear from the analysis that at most only a very slight average deviation from the metasilicate composition $RO.SiO_2$ is possible. Now we know from the microscopic study that about three-fourths of the rock is augite, which is a metasilicate having the composition of $RO.SiO_2$, where R is Fe, Ca, or Mg. It follows that the remaining quarter of the rock, consisting of a rhombic mineral, must also be a metasilicate. The preliminary petrographic examination of a thin section indicated that this rhombic mineral was either an olivine rich in enclosures, or a rhombic pyroxene with unusually high double-refraction and no pleochroism. The chemical analysis at once decides the point, for the olivines are orthosilicates having the general formula R_2SiO_4, while the rhombic pyroxenes are metasilicates ($R\ SiO_3$), and it is clearly the latter molecular composition which is indicated. The observation with the quartz-wedge (*see* p. 6), showing that the vertical axis of the rhombic crystals coincides with the axis of minimum elasticity, confirms this conclusion.

To determine whether the rhombic pyroxene is bronzite or hypersthene was the next step, and here again chemical analysis was of service. The two minerals are distinguished by the relative abundance of FeO in the base as compared with MgO, and while augite is scarcely acted on by strong hydrochloric acid, the more ferriferous rhombic pyroxenes are partially decomposed by this reagent.* A sample of the finely powdered stone was therefore digested for some hours in warm strong HCl, and the proportion of bases in the dissolved portion determined. This yielded the following results (in percentage of the whole rock) :—

FeO and Al_2O_3	8·23
CaO	0·75
MgO	2·20

The figures indicate the molecular proportions in the dissolved mineral as 39 FeO, 4 CaO, 19 MgO, so that the monoclinic pyroxene present is a variety rich in iron, having approximately the formula

* *Rosenbusch.* Mikroskopische Physiographie der petrographisch wichtigen Mineralien, Zweite Hälfte, 4. Auflage, Stuttgart 1905, pp. 204, 148.

$MgSiO_3$, $2FeSiO_3$, with a little lime replacing the other bases. This corresponds to hypersthene, and the species of the rhombic pyroxene is thus determined.

The above proportions of bases found in solution require respectively 6·90, 0·81, and 3·29 per cent of SiO_2 to form silicates of the form $RSiO_3$, so that on the assumption (which is not quite true, but probably nearly so) that all the hypersthene and none of the augite was attacked by the acid, the figures indicate that hypersthene constitutes 22 per cent of the entire stone. This is slightly less than the microscopic slide would lead us to expect, and doubtless a small proportion of hypersthene remained undissolved. The data do, however, render it clear that the lime is mainly in the augite, and on the same assumption as is made above, namely, that all the hypersthene is dissolved and all the alumina is in the augite, a simple calculation shows that the approximate composition of the augite is :—

	Percentage.	Molecular Weight.	Molecular Proportions.	
SiO_2	51·1	60·4	0·848	0·848
FeO	14·8	72	0·205	0·889
CaO	18·8	56	0 336	
MgO	13·1	40·3	0·326	
Al_2O_3	2·2	102	0·022	
	100·0			

The bases exceed the acid radical slightly in proportion, which is what we should expect from the presence of a little free iron oxide and the probability that a small proportion of the combined iron estimated as FeO is really in the form of Fe_2O_3, The result shows that the augite has approximately the formula 2FeO, 3CaO, 3MgO, $8SiO_2$, with a very little alumina, and is thus a variety rather poor in lime but fairly rich in iron. As in the case of the hypersthene, the colour in thin section is slightly weaker than the relatively high iron-content would lead us to anticipate.

The small amount of chromium indicated by the analysis is doubtless entirely in the chromite grains which are sparsely scattered through the rock. The traces of TiO_2 and MnO are most likely combined with silica in the augite and hypersthene. The small amount of H_2O indicated is probably in part hygroscopic, and in part derived from the interstitial (chloritic ?) mineral of which the petrographic examination indicated the presence in very small quantity.

5.—Position of the Nakhla Meteorite in Classification.

Meteorites are usually classified in three great divisions :—

(*a*) *Siderites*, or meteoric irons;

(*b*) *Siderolites* or *Lithosiderites*, composed of a mixture of iron and stone;

(*c*) *Aerolites* or *Lithites*, or meteoric stones.

Since our Nakhla meteorite consists entirely of stony matter, it obviously falls into the third of these great divisions, *viz.*, that of aerolites, or meteoric stones.

The aerolites or meteoric stones have themselves been variously subdivided. In the latest (1909) classification of M. Stanislas Meunier,* who has charge of the French national collection of meteorites at the Paris Museum, the stony meteorites are grouped according to their mineralogical composition and structure, as follows :—

Class.	Mineral Composition.
Chassignite	Almost entirely olivine.
Eukrite	Anorthite + olivine.
Shergottite...	Augite + maskelynite.
Shalkite	Olivine + bronzite.
Ureilite	Olivine + augite + diamond.
Angrite	Olivine + augite + monticellite.
Orgueillite...	Olivine + carbonaceous matter, earthy in structure.
Borkewelite	Olivine + carbonaceous matter, compact in structure.

The classification adopted in 1904 by Dr. Brezina,† the former

* Guide dans la Collection des Météorites. Museum National d'Histoire Naturelle, Paris, 1909, p. 13.

† Quoted in the "Catalogue of the Ward-Coonley Collection of Meteorites," by Dr. H. A. Ward. Chicago, 1904, p. 97.

curator of the great Vienna collection of meteorites, was very similar, being, for the non-chondritic stony meteorites, as follows:—

Class.	Mineral Composition.
Chladnite	Chiefly bronzite.
Veined Chladnite	Bronzite, black or metallic-veined.
Angrite	Chiefly augite.
Chassignite	Chiefly olivine.
Bustite	Bronzite + augite.
Amphoterite	Bronzite + olivine.
Rodite...	Bronzite + olivine, breccia-like.
Eukrite	Augite + anorthite.
Shergottite...	Augite + maskelynite.
Howardite...	Bronzite + olivine + augite + anorthite.
Breccia-like Howardite	Ditto, breccia-like.
Leucituranolite...	Leucite + anorthite + augite + glass.

It will be apparent that there is no precise place for the Nakhla meteorite, consisting of augite and hypersthene, in the above classifications. As augite is the principal constituent, we might class it on Dr. Brezina's scheme with the *Angrites*, a very rare type of meteorite represented by only one fall, which he defines as "chiefly augite." But the accessory mineral in the Angra dos Reis specimens is olivine,* and in our Nakhla stone it is hypersthene. A similar difficulty arises with the class *Bustite* of Dr. Brezina, which is defined as "bronzite and augite"; apart from the distinction between hypersthene and bronzite, which in itself is hardly perhaps great enough for a basis of classification, Bustite is defined by M. Meunier † as containing metallic iron in easily-visible granules, while Mr. Fletcher ‡ states that it contains "diopside, enstatite, a little anorthic felspar, with some little iron, oldhamite and osbornite."

The meteorite of El Nakhla therefore appears to be of a new type, somewhat akin to Bustite, but containing its rhombic pyroxene in the form of hypersthene, and free from felspar, metallic iron, and

* See M. Meunier's description in his "Revision des Pierres Météoriques," Autun, 1897, p. 104. Also Mr. L. Fletcher's "Introduction to the Study of Meteorites." (British Museum Guide-book), 1908, p. 45.

† "Guide," 1909, p. 13.

‡ *Loc. cit.*

sulphides. If it be desirable to give a name to a new class in which the Nakhla meteorite must at present be placed by itself, we may term it " Nakhlite," after the place of its fall, defining the term "Nakhlite" as signifying a stony non-chondritic meteorite free from metallic iron and composed essentially of augite with a subordinate amount of hypersthene.* If the rock occurred in the earth's crust, we should class it as a pyroxenite (websterite), but so long as we are ignorant of the origin of meteorites it is probably just as well to have separate names for these stones to distinguish them from terrestrial rocks.

6.—Remarks on the Origin of Meteorites.

Though not by any means common, rocks called websterites, having essentially the same composition as the Nakhla meteorite, occur in certain places in the earth's crust.† But apart from the fact that these terrestrial rocks are not found associated with active volcanoes, a consideration of the circumstances of the fall of the meteorite forbids any assumption that it can have been ejected from any existing volcano on the earth's surface. The long column of smoke, and the fused condition of the surfaces of the fragments, show that the stone must have entered the earth's atmosphere with a velocity so great as to cause intense heating, fusion, and even vaporization of the surface-portions of the stone by friction with the earth's atmosphere; and there is no earthly volcano capable of throwing out stones with a velocity at all comparable with this. We conclude that the stone came to us from space ; after a voyage lasting, it may be, for countless ages, its path approached that of the earth so closely that it was captured by the earth's attraction. The fact that the stones embedded themselves in the soil to depths of only about half a metre or less shows that the velocity with which the fragments struck the earth was of the order

* This name has already been proposed for the meteorite by M. Meunier (*Comptes Rendus* of the Paris Academy, September 4, 1911), who from a superficial examination believed it to be of a new type containing anorthite felspar. Though the stone is of a type hitherto unknown, the supposition that it was felspathic was erroneous.

† Rosenbusch, "Mikroscopische Physiographie der massigen Gesteine," Fourth Edition. Stuttgart 1907, p. 479.

of only about 100 metres a second ; but owing to the resistance of the air increasing with the approach of the meteorite to the earth's surface, the velocity must have been rapidly diminishing, and the stone at its first entry into our atmosphere must have been travelling at a speed of many kilometres a second. In fact we have no certain knowledge that meteorites differ in any essential respect from the meteors or "shooting stars" of which one can see so many on any dark night when the sky is clear, and whose velocities are known frequently to exceed 30 kilometres a second. But while the vast majority of shooting stars are so small (Newcomb and Harkness estimated the average weight to be *less than the tenth of a gramme* *) that they are entirely vaporized long before reaching the solid earth, meteorites are bodies large enough to withstand the loss by vaporization of their surface-portions and still reach the earth.

There is no reason to think that the Nakhla meteorite entered the earth's atmosphere as more than a single large stone. That it arrived in fragments is due to explosions produced by irregular stresses within the mass, caused partly by the expansion of its frictionally heated outer surfaces and partly by the compression of the air in front of it. The fragments show distinctly that there were several of these explosions at different altitudes ; for while the surfaces of some of the fragments are completely fused, other pieces show only a partial fusion, and others, again, an unfused fracture. The explosions may well have been pretty violent, for the extreme fragments were found separated by more than four kilometres, and the sound was heard for miles round.

Although meteorites are generally believed to be merely large "shooting stars," it is a curious fact that no periodicity has been noticed in their fall comparable with that of meteor-showers. Shooting stars, though they can be seen all the year round, are most numerous at certain seasons, when the earth is at definite points of its orbit ; meteors are abundantly seen, for instance, in November and August of most years. But of the hundreds of recorded falls of meteorites on

* See Young, "General Astronomy," 1904, p. 474.

the earth, only one is known to have occurred during a meteor-shower. The Nakhla meteorite fell in June, a time of year when no unusual abundance of shooting stars is remarked.

Nor is there any distinct reason for thinking that one part of the earth's surface is more favoured than another by these heaven-sent stones. If the different sites were plotted on a map, we should find the dots clustering in the civilized countries and largely absent from the deserts; but we should be recording, not falls, but *finds.*

If a rock of the same composition and structure as the Nakhla meteorite were found in the earth's crust, we should be fairly certain, in accordance with generally-accepted geological views, that it had originated by the cooling and solidification of a liquid magma under plutonic conditions—that is, at some depth within the earth's crust—and had been exposed by subsequent denudation. And though of course we have no proof that the Nakhla stone originated in a similar manner, still it is natural to imagine that, like terrestrial rocks, the meteorite represents the solidification of a magma either in the earth or in some heavenly body. On this hypothesis it is possible to obtain some idea of the temperature at which the stone was formed. The chemical analysis shows the meteorite to consist of meta-silicates in which the porportion of magnesium and iron to calcium is about 68 to 32, and the melting-point, at the atmospheric pressure, of a magma having this composition, is known from Vogt's researches * to be about 1250° C. If, as is probable from the state of crystallization of the stone, solidification took place under considerable pressure, the temperature must have been lower than 1250° C.

Some support to the hypothesis that the meteorite originated by solidification of a fused magma is afforded by a comparison of the manner in which the two main minerals of the rock are crystallized. The augite shows a marked tendency to idiomorphism while the hypersthene does not. Now Vogt found by experiment that the eutectic mixture (*i.e.*, a mixture which would solidify as a whole) of hedenbergite (a lime-iron augite) and hypersthene contains about 40 of the

* Quoted by Harker, "The Natural History of Igneous Rocks." London, 1909, p. 177.

augite to 60 of pyroxene. And as this proportion of augite is much exceeded in our stone, we have an easy explanation why the augite got a start in crystallization.

The friability of the interior of the stone, too, is in accordance with the idea of its having been shot off from a body similar to the earth into the intense cold of space. Here in the tropics especially we are familiar with the disintegration of rocks by changes of temperature. The component crystals of such rocks as granite, for instance, with their different coefficients of expansion in different directions, are rapidly separated by even such moderate temperature-variations as occur at the earth's surface; and we can easily understand that a sudden cooling down from say 20° C. to —270° C. would produce just such a friability as we see in the Nakhla meteorite. This does not *prove* the meteorite to have been projected into space, however, for the same effect would result from the reverse movement, which we know to have taken place, namely, the sudden passage from cold space into the heated atmosphere of the earth.

As to the primary source of meteorites, nothing is known with certainty, though various speculations have been made. In these speculations one has to consider, not the evidence gatherable from a single meteorite, but that obtainable from all the other known falls, and also a large number of ascertained facts in observational and dynamical astronomy. Countless swarms of meteors are known to exist in space, and we have no good reasons for concluding that the meteors of these swarms originate differently from those which reach the earth.

Amongst the hypotheses which have been advanced as to the origin of meteorites, the following may be noted :—

(*a*) That they are miracles.

(*b*) That they represent a primitive state of matter antedating the formation of worlds like the sun, stars and planets.

(*c*) That they have been shot out from the sun.

(*d*) That they represent a broken up planet.

(*e*) That they have been ejected from volcanoes of the moon.

(*f*) That they represent a broken-up terrestrial satellite.

(*g*) That they have been shot out from terrestrial volcanoes in past ages of the earth's history.

In ancient times, stones which had fallen from the sky were regarded as coming from the gods, and were objects of veneration. The sacred black stone of the Kaaba at Mecca is believed to be a meteorite, and the earliest meteorite of which the date of fall is known (1492) was long suspended by a chain from the vault of the choir in the parish church of Ensisheim in Alsace.

The second view mentioned above represents the meteoritic hypothesis, strongly advocated by Sir Norman Lockyer, according to which the heavenly bodies have all been formed by the aggregation of meteorites rather than by the condensation of gaseous nebulae. Lockyer finds in the spectra of meteorites under different conditions the same lines and flutings as occur in the spectra of comets, nebulae, and stars, as well as in the spectra of the Aurora borealis and the Zodiacal light. A swarm of fast-moving meteorites, seen from stellar distances, would behave like a mass of continuous gas; in fact, the kinetic theory of gases assumes that a gas is a sort of meteoritic swarm on a minute scale, with swiftly-moving molecules instead of meteorites. The known connection between comets and meteors, and the phenomena of new and variable stars, are all explainable on this hypothesis, but it presents some difficulties which have prevented its universal acceptance.

The general similarity of composition of large numbers of known meteorites, and especially the exceedingly frequent presence of metallic iron and nickel, is suggestive of an origin from the breaking up of a single heavenly body.

The idea that meteorites are ejected from the sun is opposed by the apparently fatal objection that some of the constituents found in meteorites, such as free phosphorus and carbon, are easily combustible.

That meteorites represent a broken-up planet, perhaps a part of the same one which has been imagined to have given rise by its break-up to the asteroids, is rather an attractive speculation; but there is no direct evidence favouring this view. On the one hand, the nearest of the asteroids, Eros, never approaches the earth closer than 13 million miles; and on the other hand, an investigation of the paths of three meteorites of similar composition (eukrites) led von Niessl* to the conclusion that if they were derived from the breaking-up of a single body, the explosion must have occurred at a distance far greater than that of the known planets.

The supposition that meteorites may be the product of lunar activity is perhaps natural to anyone who views the huge lunar craters through a telescope. But there are no signs of lunar activity in the present day, and though gigantic volcanic forces have been in action on our satellite in the past, Sir Robert Ball† has shown that if a mass projected from the moon once missed the earth, the chances are almost infinitely against it ever reaching our globe subsequently. That the density of the Nakhla meteorite (3·4) is exactly that of the moon, is a mere coincidence from which nothing can be inferred, for many other meteorites vary considerably from this in density.

That another satellite of the earth, smaller than the moon, has broken up, and that the meteorites which reach the earth are the products of its disintegration, has been argued by M. Meunier; but it is difficult to see how this can have happened without our receiving some of the larger fragments which must have been produced.

The terrestrial origin of meteorites as ejections from volcanoes in remote ages of the earth's history is perhaps the idea most acceptable to astronomers and geologists at the present time. The mean density of the earth is 5·5, while that of its outer crust is only about 2·7. Meteorites of the stony variety usually have densities of over 3, and in those containing iron the specific gravity may rise to nearly 8. In addition to their high specific gravity, meteorites frequently differ from known terrestrial rocks not only in structure, but in containing substances, such as carbides and phosphides, unknown as terrestrial minerals, and also in that some of the commonest terrestrial minerals, such as quartz, are not found in meteorites. It is thus evident that if meteorites have originated from the earth, they are not portions of its

* Sitzb. Wiener Akad., Bd. 113 (2a), 1904, pp. 1361-1419.

† Speculations on the Source of Meteorites. *Nature*, 1879, vol. 19, p. 493.

present-day crust, but are derived from the interior. As already remarked, no existing volcano is anything like powerful enough to eject great masses with sufficient velocity to carry them through the earth's atmosphere. Nor have we any evidence that it was otherwise during the ages throughout which the known geological formations were being deposited. But vast as is the time covered by the geological record, there were prior ages of which we know nothing, when the crust was not yet cool and solid, and it may easily be that meteorites were then ejected, to travel in unknown orbits in space for millions of years before coming to earth again. That the minerals composing the Nakhla meteorite are found in a much fresher state than they usually are in similar rocks at the earth's surface, is not inconsistent with the idea that the meteorite may be vastly older than any terrestrial rock known to us; for it hardly needs pointing out that one of the principal weathering influences, moisture, is absent from the realms of space, where chemical action will also be lessened by the intense cold.

7.—Possibility of Further Finds of Meteorites in Egypt.

Though the Nakhla meteorite is the first of which fragments are known to have been found in Egypt, it is always possible that specimens may be found from previous falls on the bare deserts which form nine-tenths of the Egyptian territory. I believe a large meteorite fell to the north-west of Aswan on April 5, 1902. On that date, while I was engaged in my office on Philæ Island, just before 5 o'clock in the afternoon, I was suddenly called out by one of my English foremen to look at a remarkable object which had appeared in the sky, in full sunlight. What I saw was a nearly vertical column of white smoke, about a degree in diameter and ten degrees in length, with its lower end about five degrees above the horizon. My foreman, who had observed its arrival, reported that the meteorite looked like a cannon-ball of intensely brilliant reddish-yellow light, darting downwards with a streak of flame behind it and leaving the column of white smoke which I saw. The foreman said it seemed to him to suddenly burst and fall as a black mass on reaching the altitude of about 5°. I took a bearing on to the smoke-column, which gave its direction from Philæ (north-west corner) as 32° west of true north. I observed that the column remained unbroken, slowly descending, for 15 minutes; then gradually breaking up, it was visible as a white cloud for about an hour longer. I was in hopes that someone else might have taken a bearing to the smoke-column from another place, and thus enabled its distance to be determined, but could not hear of such an observation. I sent two mounted Arabs off in the direction given for some 20 miles with instructions to look for strange heavy black stones in the desert, but although I offered a liberal reward they had no success. The difficulty is to guess the distance of the object from a single observation, but from the size of the smoke-column and the brilliance of the meteor I imagine it cannot have been many miles away. Of course, the foreman may have been mistaken in thinking that he saw a black mass fall, or if it reached the earth, the mass may have buried itself in the blown sand of the desert; but for anyone who is interested and could camp for a week or so in the desert there is a reasonable sporting chance of finding a large meteorite by searching along a line bearing 32° west of true north from Philæ island. As meteorites are usually worth at least their weight in silver, and sometimes as much as five or six times their weight in gold, the searcher would, in the event of success, recoup himself handsomely for any outlay he might make in his quest.

SHORT CATALOGUE

OF THE

MAPS, PLANS, AND PUBLICATIONS

ISSUED BY THE

SURVEY DEPARTMENT, MINISTRY OF FINANCE, EGYPT.

MAPS AND PLANS.

The following is a general list of the maps and plans offered for sale by the Survey Department. A booklet giving details of all sheets printed may be obtained free, on application either personally or by letter at the Headquarters of the Department, Giza (Mudiria), or at the Geological Museum, Public Works Ministry Gardens, Cairo, where all maps and plans are for sale, or through any bookseller.

Except where specially stated, the price of each map-sheet is 50 milliemes on paper, and 65 milliemes on cloth, and they are sent post free by the Department.

The reference marks denote: (*) map is in Arabic only; (†) map is in English only; (*†) map bears place-names both in Arabic and English; (*) (†) map can be obtained either in Arabic or English.

Town Maps.

The following list gives particulars of the maps published. The map of Alexandria, on the scale of 1 : 1,000 will be completed during 1911. The survey of Cairo on the scale of 1 : 1,000 is in progress.

Cairo (*†), 30 sheets, scale 1 : 1,000 (in preparation).
Alexandria (*†), 147 sheets, scale 1 : 1,000.
General map of Alexandria Municipality (French and Arabic), 10 sheets scale 1 : 6,000.
Mit Ghamr (*†), 4 sheets, scale 1 : 1,000.
Mansura (*†), 16 sheets, scale 1 : 1,000.
Suez (*†), 20 sheets, scale 1 : 1,000.
Suez (*†), 1 sheet, scale 1 : 2,500.
Sohag (*†), 6 sheets, 1 : 1,000.
Tanta (*†), 15 sheets, scale 1 : 1,000.
Girga (*†), 6 sheets, scale 1 : 1,000.
Aswan (*†), 23 sheets, scale 1 : 1,000.
Port Said (in French), 1 sheet, scale 1 : 5,000.
Zagazig (*†), 20 sheets, scale 1 : 1,000.
Damanhur (*†), 14 sheets, scale 1 : 1,000.
Benha (*†), 25 sheets, scale 1 : 1,000.

£ 1 = 975 milliemes; $ 1 = 200 milliemes; Mk. 1 = 48 milliemes; Fr. 1 = 38 milliemes.

Cadastral Maps.

These are maps of the villages showing each *hod* and plot of land. They are printed in Arabic only. In ordering, the name of the village and the numbers of *hod* and plot should be given. The following list gives the particulars of the maps for each mudiria (province):—

Beheira mudiria (*), 3,300 sheets, under survey, scale 1 : 2,500.
Gharbia mudiria (*), 3,460 sheets, scale 1 : 4,000 and 1 : 2,500.
Daqahlia mudiria (*), 2,237 sheets, scale 1 : 2,500.
Sharqia mudiria (*), 2,974 sheets, scale 1 : 2,500.
Menufia mudiria (*), 2,173 sheets, scale 1 : 4,000 and 1 : 2,500.
Qaliubia mudiria (*), 778 sheets, scale 1 : 2,500.
Giza mudiria (*), 766 sheets, scale 1 : 4,000.
Fayum mudiria (*), 2,263 sheets, scale 1 : 2,500.
Beni Suef mudiria (*), 942 sheets, scale 1 : 2,500.
Minia mudiria (*), 1,635 sheets, scale 1 : 2,500.
Assiut mudiria, including Kharga Oasis (*), 2,273 sheets, scale 1 : 2,500.
Girga mudiria (*), 1,313 sheets, scale 1 : 2,500.
Qena mudiria (*), 1,568 sheets, scale 1 : 2,500.
Aswan mudiria (*), 1,076 sheets, scale 1 : 2,500.

Topographical Maps.

Scale 1 : 10,000 (10 cm. = 1 kilometre; 6·3 inches = 1 mile).—The names on these maps are in most cases in Arabic and English. The following table shows the number of sheets published :—

Beheira mudiria (*), 260 sheets.
Gharbia mudiria (*†), 213 sheets.
Sharqia mudiria (*†), 29 sheets.
Daqahlia mudiria (*†), 11 sheets.
Menufia mudiria (*†), 73 sheets.
Qaliubia mudiria (*†), 65 sheets.
Giza mudiria (*†), 90 sheets.
Fayum mudiria (*†), 126 sheets.
Beni Suef mudiria (*†), 21 sheets.
Assiut mudiria, including Kharga Oasis (*†), 72 sheets.
Aswan mudiria (*†), 63 sheets.
Aswan or First Cataract (†), 6 sheets.
The Nile Valley from Aswan to Korosko (†), 36 sheets (paper only, 25 milliemes each).

Scale 1 : 25,000 (4 cm. = 1 kilometre; 2·5 inches = 1 mile).— A provisional map of Northern Gharbia has been published on this scale, pending the publication of the 1 : 10,000 sheets of this area. There are 91 sheets.

Scale 1 : 50,000 (2 cm. = 1 kilometre; 1·3 inches = 1 mile).—These maps are printed in three colours. Names are given in English, and as a rule in Arabic as well. This series is completed for the whole of the cultivated area of the Nile Valley and Delta. There are 145 sheets.

Scale 1 : 1,000,000 (1 cm. = 10 kilometres; 1 inch = 16 miles).—The six sheets of this map, covering the whole of Egypt, have now been published. The names are in English. The price of each sheet is 50 and 65 milliemes for paper and cloth editions respectively, or the whole can be obtained mounted on cloth, varnished, and fitted with rollers for 550 milliemes.

Special Maps on Various Scales.

Map of the Delta (†), 4 sheets, scale 1 : 200,000. Price, 75 milliemes per sheet, or the complete map mounted on cloth, varnished and fitted with rollers, 700 milliemes.

Lower Egypt and the Fayum, 1904 (latest edition) (†), 1 sheet, scale 1 : 500,000.

Lower Egypt, showing lines of communication (†), 1 sheet, scale 1 : 500,000.

Northern Gharbia (*†), 1 sheet, scale 1 : 200,000.

Kharga Oasis (†), 1 sheet, scale 1 : 500,000.

Dakhla Oasis (†), 1 sheet, scale 1 : 500,000.

Baharia Oasis (†), 1 sheet, scale 1 : 500,000.

Farafra and Iddalia Oases (†), 1 sheet, scale 1 : 500,000.

Provisional map of the Eastern Desert of Egypt, East Qena-Aswan to Red Sea (†), 20 sheets, scale 1 : 100,000.

Provisional map of the Eastern Desert of Egypt, between Qus, Sayala and Red Sea (†), 2 sheets, scale 1 : 500,000.

Provisional map of a part of the Eastern Desert Oilfield (†), 1 sheet, scale 1 : 100,000. Price, 100 milliemes on paper and 150 milliemes on cloth.

Provisional map of a part of the Eastern Desert Oilfield, showing registered prospecting areas (†), 1 sheet, scale 1 : 100,000. Price, 100 milliemes on paper and 150 milliemes on cloth.

Red Sea and Sinai Oilfield, showing registered prospecting areas (†), 1 sheet, scale 1 : 316,800. Price, 100 milliemes on paper and 150 milliemes on cloth.

Jemsa Oil Zone (†), 1 sheet, scale 1 : 75,000 and 1 : 250,000. Price, 50 milliemes.

Mersa Matruh chart (†), 1 sheet, scale 1 : 4,500.

Mersa Matruh topographical map (†), 1 sheet, scale 1 : 10,000.

Mersa Matruh and Ras Allam Rum (†), 2 sheets, scale 1 : 25,000.

Aqaba-Rafa, 1906 (*†), 3 sheets, scale 1 : 100,000.

Aqaba-Rafa, 1906 (*) (†), 1 sheet, scale 1 : 500,000 (paper, 25 milliemes; cloth, 40 milliemes).

The Nile Valley from Aswan to Sudan boundary (†), 1 sheet, scale 1:250,000.

Port d'Alexandrie (French), 3 sheets, scale 1 : 4,000.

Wall-Maps, for use in Schools.

The price of each map is 700 milliemes, except that of the Mediterranean Basin, which is 500 milliemes. Each map is mounted on cloth, varnished, and fitted with rollers. The following list gives the maps published and in preparation :—

Africa (physical) (*), scale 1 : 6,000,000.
Africa (political) (*), scale 1 : 6,000,000.
The Nile Basin (*) (†), scale 1 : 2,500,000.
Egypt (*) (†), scale 1 : 750,000.
The Delta and the Fayum (*), scale 1 : 200,000.
Mediterranean Basin (*), scale 1 : 3,000,000.
Western Europe and the British Isles (*), scale 1 : 1,500,000
Asia (physical) (*), scale 1 : 6,000,000.
Asia (political) (*), scale 1 : 6,000,000.
Europe (physical) (*), scale 1 : 3,000,000.
Europe (political) (*), scale 1 : 3,000,000.
The World (*) (Mercator's projection).
The Hemispheres (Eastern and Western) (Airy's projection)
British Isles, scale 1 : 750,000.
North America (*) (physical) 1 : 6,000,000.
North America (*) (political) 1 : 6,000,000.

Wall-Maps for use in Schools *(continued).*

IN PREPARATION :—

South America (physical) 1 : 6,000,000.
South America (political) 1 : 6,000,000.

Geological Maps.

Geological map of Egypt, scale 1 : 1,000,000. English. Six sheets, 70 × 58 cm. Price, 100 milliemes per sheet. Complete map, mounted on cloth, varnished and fitted with rollers, 850 milliemes.

Geological map of Egypt, scale 1 : 2,000,000. English. One sheet, 68½ × 67 cm. Price, 200 milliemes on paper, and 300 milliemes mounted on cloth and fitted with rollers.

A number of maps have been published in the various Geological reports. Further information may be obtained under the respective headings in the list of Geological Reports, pp. V and VI.

PUBLICATIONS.

The following is a general list of the publications of the Survey Department, and a few others which are for sale at the Headquarters of the Department, Giza (Mudiria), and at the Geological Museum, Public Works Ministry Gardens, Cairo. A booklet giving full details can be obtained, on application either personally or by letter.

Except where specially stated, the publications are 8vo, and in English, and are supplied post free by the Department. They can also be obtained through any bookseller.

Archæology.

ARCHÆOLOGICAL SURVEY OF NUBIA.

BULLETIN 1.—Dealing with the work (archæological and anatomical) from September 20 to November 30, 1907. English. 39 pp., 27 illustrations. (Out of print).

BULLETIN 2.—Dealing with the work (archæological and anatomical) from December 1, 1907, to March 31, 1908. English. 69 pp., 52 illustrations. Price, 100 milliemes.

BULLETIN 3.—Dealing with the work (archæological and anatomical) from October 1 to December 31, 1908. English. 52 pp., 5 illustrations. Price, 100 milliemes.

BULLETIN 4.—Dealing with the work (archæological and anatomical) from January 1 to March 31, 1909. English. 28 pp., 2 illustrations. Price, 100 milliemes.

BULLETIN 5.—Dealing with the work (archæological and anatomical) from October 1 to December 31, 1909. English. 35 pp., 5 illustrations. Price, 100 milliemes.

BULLETIN 6.—Dealing with the work (archæological and anatomical) from January 1 to April 15, 1910. English. 30 pp., 8 illustrations. Price, 100 milliemes.

Archæology—*continued.*

ANNUAL REPORT OF THE ARCHÆOLOGICAL SURVEY OF NUBIA, SEASON 1907-8. VOL. I: by GEORGE A. REISNER. Price, with volume of plates, L.E. 2.

ANNUAL REPORT OF THE ARCHÆOLOGICAL SURVEY OF NUBIA, SEA ON 1907-8. VOL. II: Report on the Human Remains, by Dr. G. ELLIOT SMITH, F.R.S., and Dr. F. WOOD JONES. Price, with volume of plates, L.E. 2.

PHILÆ,—REPORT ON THE ISLAND AND TEMPLES OF, by CAPT. H. G. LYONS, with introductory note by W. E. GARSTIN. 1896. English. 67 pp., 78 illustrations. (Out of print).

PHILÆ,—REPORT ON THE ISLAND AND TEMPLES OF, by CAPT. H. G. LYONS. 1908. English. 4to, 32 pp., 14 illustrations. Price, 200 milliemes.

Geography.

RIVER NILE AND ITS BASIN—PHYSIOGRAPHY OF THE, by CAPT. H. G. LYONS. 1906. 411 pp., 14 maps, 34 illustrations. Price, 400 milliemes.

TURCO-EGYPTIAN BOUNDARY BETWEEN THE VILAYET OF THE HEJAZ AND THE PENINSULA OF SINAI—THE DELIMITATION OF THE, by E. B. H. WADE, together with additions by B. F. E. KEELING and J. I. CRAIG. 1906. (Survey Department Paper, No. 4). 89 pp., 2 maps. Price, 150 milliemes. See also Geology.

Geology.

ABU ROASH, NEAR THE PYRAMIDS OF GIZA—CRETACEOUS REGION OF, by H. J. L. BEADNELL. 1902. 48 pp., 2 maps, 19 illust. Price, 200 milliemes.

ARSINOITHERIUM ZITTELI (Beadnell), FROM THE UPPER EOCENE STRATA OF EGYPT—PRELIMINARY NOTE ON, by H. J. L. BEADNELL. 1902. 4 pp., 6 illustrations. Price, 50 milliemes.

ASWAN (FIRST) CATARACT OF THE NILE—DESCRIPTION OF, by DR. BALL. 1907. 121 pp., 5 maps, 28 illustrations. Price, 200 milliemes.

BAHARIA OASIS, ITS TOPOGRAPHY AND GEOLOGY, by DR. BALL and H.J.L. BEADNELL. 1903. 84 pp., 8 maps, 2 illust. Price, 200 milliemes.

BLACKENED ROCKS OF THE NILE CATARACTS AND OF THE EGYPTIAN DESERTS, by A. LUCAS. 1905. 58 pp. Price, 100 milliemes.

BUILDING STONES IN EGYPT—DISINTEGRATION OF, by A. LUCAS. 1902. 17 pp. Price, 75 milliemes.

BUILDING STONES OF CAIRO NEIGHBOURHOOD AND UPPER EGYPT, by DR. HUME. 1909. 92 pp., 9 illustrations. Price, 150 milliemes. Survey Department Paper, No. 16.

CAIRO AND SUEZ—TOPOGRAPHY AND GEOLOGY OF THE DISTRICT BETWEEN, by T. BARRON. 1907. 133 pp., 2 maps, 14 illustrations. Price, 200 milliemes.

CATALOGUE OF THE GEOLOGICAL MUSEUM, CAIRO, by DR. HUME. 1905. 37 pp. Price, 25 milliemes.

Geology—*continued.*

DAKHLA OASIS, ITS TOPOGRAPHY AND GEOLOGY, by H. J. L. BEADNELL. 1901. 107 pp., 9 maps, 7 illustrations. Price, 200 milliemes.

EASTERN DESERT OF EGYPT, CENTRAL PORTION—TOPOGRAPHY AND GEOLOGY OF, by T. BARRON and DR. HUME. 1902. 331 pp., 10 maps, 30 illust. Price, 400 milliemes.

EASTERN DESERT OF EGYPT, BETWEEN LATITUDES 22° AND 25° N.—PRELIMINARY REPORT ON GEOLOGY OF, by DR. HUME. 1907. 72 pp., 4 maps, 5 illust. Price, 150 milliemes. Survey Department Paper, No. 1.

FARAFRA OASIS, ITS TOPOGRAPHY AND GEOLOGY, by H. J. L. BEADNELL. 1901. 39 pp., 8 maps. Price, 150 milliemes.

FAYUM PROVINCE OF EGYPT—TOPOGRAPHY AND GEOLOGY OF, by H.J.L. BEADNELL. 1905. 101 pp., 2 maps, 22 illustrations. Price, 300 milliemes.

FORÊTS PÉTRIFIÉES DES DÉSERTS DE L'EGYPTE—NOTE SUR L'ÂGE DES, par M. R. FOURTEAU. 1898. French. 8 pp. (Out of print).

IRON ORES IN EGYPT—DISTRIBUTION OF, by DR. HUME. 1909. 16 pp., 1 map. Price, 50 milliemes. Survey Department Paper, No. 20.

JEBEL GARRA AND THE OASIS OF KURKUR—TOPOGRAPHICAL AND GEOLOGICAL RESULTS OF A RECONNAISSANCE-SURVEY OF, by DR. BALL. 1902. 40 pp., 2 maps, 5 illustrations. Price 150 milliemes.

KHARGA OASIS, ITS TOPOGRAPHY AND GEOLOGY, by DR. BALL. 1900. 116 pp., 19 maps, 16 illustrations. Price, 250 milliemes.

MAMMALS—PRELIMINARY NOTE ON SOME NEW—FROM THE UPPER EOCENE OF THE FAYUM, EGYPT, by C. W. ANDREWS and H. J. L. BEADNELL. 1902. 9 pp., 4 illustrations. Price, 100 milliemes.

PÉTROLE DE LA MER ROUGE—RAPPORT SUR LES RECHERCHES DU, par J. BAROIS. 1885. French. 16 pp., 1 map, 10 illustrations. Price, 100 milliemes.

PETROLEUM DISTRICTS SITUATED ON THE RED SEA COAST—REPORT ON, by COL. C.E. STEWART. 1888. 25 pp. Price, 100 milliemes.

PETROLEUM INDUSTRY AT BAKU—SKETCH REPORT OF, by J. H. TREVITHICK. May, 1886. 22 pp. Price, 100 milliemes.

PHOSPHATE DEPOSITS OF EGYPT, by SURVEY DEPARTMENT, 2nd edition 1905. 35 pp., 3 maps. Price, 50 milliemes.

SINAI PENINSULA (SOUTH-EASTERN PORTION)—TOPOGRAPHY AND GEOLOGY OF, by DR. HUME. 1906. 280 pp., 5 maps, 23 illustrations. Price, 300 milliemes.

SINAI PENINSULA (WESTERN PORTION)—TOPOGRAPHY AND GEOLOGY OF, by T. BARRON. 1907. 241 pp., 2 maps, 13 illustrations. Price, 300 milliemes.

SOIL AND WATER OF THE FAYUM PROVINCE—PRELIMINARY INVESTIGATION OF, by A. LUCAS. 1902. 17 pp. Price, 75 milliemes.

Geology—*continued.*

SOIL AND WATER OF THE WADI TUMILAT LANDS UNDER RECLAMATION, by A. LUCAS. 1903. 26 pp., 1 map, 5 illustrations. Price, 100 milliemes.

SUBSOIL WATER IN LOWER EGYPT—PRELIMINARY NOTE ON THE, by H. T. FERRAR, M.A., F.G.S. 1910. 16 pp., 3 illustrations. Price, 50 milliemes.

THE MOVEMENTS OF THE SUBSOIL WATER IN UPPER EGYPT, BY H. T. FERRAR, M.A., F.G.S. Survey Department Paper, No. 19. English. 74 pp., 32 illustrations and 16 maps. Price, 150 milliemes.

TERTIARY VERTEBRATA OF THE FAYUM, EGYPT—DESCRIPTIVE CATALOGUE OF, by C. W. ANDREWS. 1906. 319 pp., 124 illustrations.

TORTOISE—LAND—FROM THE UPPER EOCENE OF THE FAYUM, EGYPT—PRELIMINARY NOTICE OF, by C.W. ANDREWS and H.J.L. BEADNELL. 1903. 11 pp., 3 illustrations. Price, 50 milliemes.

Meteorology.

DAILY WEATHER REPORT.—Issued daily by the Survey Department. Contains the readings taken at 29 stations in Egypt and the Sudan, and five stations in southern Europe, with a map showing the distribution of pressure. Post free, 200 milliemes quarterly, including short monthly summary.

SUMMARY OF THE WEATHER IN EGYPT, SUDAN, AND THE SURROUNDING REGION. Monthly.—Contains a brief report on the weather for the month, with maps showing the pressure-distribution for each day. Price, post free, 300 milliemes per annum.

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