ON SAND-BARITES FROM KHARGA, EGYPT.

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Introduction.—Calcite, gypsum, and barite are distinguished, above all other minerals, by the large quantities of sand which they can inclose upon crystallization, without being materially hindered in the development of crystal outline. As examples of the first, there come to mind the well-known sand-calcites of Fontainebleau, France, containing 50 to 60 per cent sand, which have been described by Lassone [a] and Haüy; [b] and the siliceous calcites from the Bad Lands of South Dakota, with 60 to 63 per cent of rounded quartz grains, accounts of which have been given by Penfield and Ford [c] and by Barbour.[d] Examples of the second are not so familiar, but gypsum including fine sand is found in Sussex, New Brunswick;[e] Carcote, Bolivia;[f] and some other localities. Sand-barites are also uncommon. It is the purpose of this paper to recount the localities where these, as well as baritic sandstones, occur; and to describe, from a new locality,[g] an unusually full suite of crystals and groups acquired in November, 1909, by the U. S. National Museum (Cat. No. 86580).

Historical.—The first mention of arenaceous barites appears to be in 1853, when Reuss[h] called attention to thin tabular crystals inclosing much sand, which had been discovered at Tetschen, near Trebnitz, Bohemia.

[a] Mem. Acad. Roy. Paris, 1775, p. 65.

[b] Traite de Mineralogie, vol. 1, 1822, p. 424.

[c] Amer. Journ. Sci., vol. 9, 1900, pp. 352–354.

[d] Bull. Geol. Soc. Amer., vol. 12, 1901, pp. 165–178. Also Barbour and Fisher, Amer. Journ. Sci., vol. 14, 1902, pp. 451–454.

[e] Amer. Journ. Sci., vol. 35, 1863, p. 213.

[f] Verh. Verein Santiago, Chile, vol. 2, 1892, p. 238.

[g] M. J. Couyat (La célestite et la barytite d'Egypte. Bull. Soc. Min. France, vol. 31, 1908, p. 298) devotes a half page to a brief account of clear crystals of barite from Kharga, showing the following forms: (001), (110), (011), (010), (130), (210), (102), (111). These, however, do not contain sand.

[h] A. E. Reuss, [Note], Lotos, Zeitschr. für Naturw., Prague, vol. 3, 1853, p. 72.

The following year Bischof[a] stated that sandstone cemented by barium sulphate occurs at Münzenberg, in the Wetterau district of Germany; and that in the district of Kreuznach and near Leipzig, Germany, and in the vicinity of Bologna, Italy, are found globular concretions composed of sand, barite, and some clay.

In 1868 Laspeyres,[b] in discussing the wells near Dürkheim, in Bavaria, Germany, said that baritic sandstone had been encountered in a bore hole at depths of 330 and 820 feet.

In 1883 Zittel[c] reported that, during an exploration of the Lybian Desert of northeastern Africa, he had gathered rounded and slightly flattened sand-barite concretions from the isolated mountain of Gella Siui, between Bauite and Häss.

In 1889 Clowes[d] announced that some of the Triassic sandstones near Nottingham, England, are cemented with 33 to 50 per cent barium sulphate. He directed attention in particular to a sandstone pillar, some 30 feet in height and 70 feet in circumference, which is crowned by a flattened mushroom-like cap of baritic sandstone.

In 1897 Polak[e] described crystals of barite from a railroad cut near Tetschen-Bodenbach, Bohemia, and said that some of these contain included quartz grains.

The year following, Moore[f] added another locality, near Bidston Hill, in the Triassic of England. There the barite is present in quantities up to 34 per cent as a cement in globular sand concretions, the size of walnuts, which weather out from the sandstone.

In 1899 Clowes[g] referred to his previous communication, and stated further that barium sulphate is not rare among the Triassic sandstones of England. The same year, Wedd[h] mentioned the presence of baritic sandstone in North Staffordshire.

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[a] G. Bischof, Chemical and Physical Geology, vol. 1, 1854, p. 433.

[b] H. Laspeyres, Kreuznach und Dürkheim a. d. Hardt. Zeitschr. Deutsch. Geol. Ges., vol. 20, 1868, p. 174.

[c] K. A. Zittel, Beitrage zur geologie der Libyschen Wüste. Palaeontographica, vol. 30, 1883, p. 121.

[d] F. Clowes, Barium sulphate as a cement in sandstone. Proc. Roy. Soc., vol. 46, 1889, pp. 363–368.

[e] J. M. Polak, Ueber Baryt krystalle von der Bohemia bei Tetschen-Bodenbach. Sitzungsb. Deutsch. Nat. Med. Ver. Lotos. Prague, vol. 17, 1897, pp. 78–80.

[f] C. C. Moore, The Chemical examination of sandstone from Prenton Hill and Bidston Hill. Proc. Liverpool Geol. Soc., vol. 8, 1898, pp. 241–267. Especially pp. 266–267.

[g] F. Clowes, Deposition of barium sulphate as a cementing material in sandstone. Proc. Roy. Soc., vol. 64, 1899, pp. 374–377.

[h] C. B. Wedd, Note on barium sulphate in the Bunter sandstone of North Staffordshire. Geol. Mag., vol. 6, 1899, p. 508.

In 1900 Delkeskamp[a] gave an extensive paper on sand-barites in the Wetterau and Rheinhessen districts of Germany, in which he described rosettes and concretionary forms from the Tertiary sandstones. The concretions are sometimes hollow and contain barite crystals.

In 1901, Beadnell[b] found numerous specimens of "crystallized barytes-sandstone" in the Dakhla Oasis of Egypt. These are briefly described as tabular crystals, often intergrown into masses of various sizes, and having a specific gravity of 3.25 and silica content of 55 per cent. In the same year Mackie[c] cited the occurrence of arenaceous barite in the form of nodules disseminated through the Triassic sandstone along the coast of Elginshire, England.

In 1902, Delkeskamp [d] included in a second paper an account of the sand-barites from Rockenberg and Vilbel, Wetterau; and Kreuznach, Rheinhessen. In Rockenberg occur well-developed rosettes or "roses," often uniting in extensive groups; and larger, spherical concretions, frequently slightly intergrown.[e] The Vilbel forms are prominently tabular and simpler. The Kreuznach individuals are mostly spherical and possess an inner radial structure; they are frequently intergrown and show strange shapes, resembling pears, turnips, etc. From 20 to 30 per cent sand is present in the various occurrences.

In 1906 Nichols[f] described sand-barites from near Muskogee, Oklahoma. These are rosettes made of intergrown plates and are somewhat rounded by wind action. The content of angular quartz fragments is 37 per cent. The U. S. National Museum possesses specimens from near Bavaria, Saline County, Kansas (Cat. No. 85275), which are very similar to those from Oklahoma.

Occurrence.—The specimens to be herein described were collected by Dr. A. Hrdlička, of the U. S. National Museum, while on an anthropological expedition to Egypt in 1909. They occur in the Lybian Desert, and more particularly in the central part of the Kharga

[a] R. Delkeskamp, Schwerspatvorhommnisse in der Wetterau und Rheinhessen und ihre Entstehung. Notizbl. Ver. Erdkunde, vol. 21, 1900, pp. 47–83.

[b] H. J. L. Beadnell, Dakhla Oasis: Its topography and geology. Egypt. Geol. Surv. Rept., 1901.

[c] W. Mackie, The occurrence of barium sulphate and calcium fluoride as cementing substances in the Elgin Trias. Rep. Brit. Ass. Adv. Sci., 1901, p. 649.

[d] R. Delkeskamp. Ueber die Krystallisationsfähigkeit von Kalkspat, Schwerspat, und Gyps bei ungewöhnlich grosser Menge eingeschlossenen Quarzsandes. Zeitschr. Naturw., Halle, vol. 75, 1902, pp. 185–208.

[e] The National Museum possesses specimens from Rockenberg, Cat. No. 80612.

[f] H. W. Nichols, Sand-barite crystals from Oklahoma. [*In* New forms of concretions.] Publ. Field Col. Mus., Geol. Ser., publ. 111, vol. 3, 1906, pp. 31–35.

Oasis near the village of Kharga, which is about 300 miles south of Cairo and nearly 100 miles west of the Nile. There are several ranges of small mountains within the oasis, and in the foothills of one of these, on a conical hill about 20 feet high, the specimens were found lying loose in the sand. In a few places is exposed the solid rock, which is doubtless the Nubian sandstone of Upper Cretaceous age, that plays so important a part in the scenery of northeastern Africa.[a]

To convey a better idea of the region, the following description is excerpted from an article by a former member of the Egyptian Geological Survey:

> The Lybian Desert is the easternmost and most unhospitable portion of the Sahara or Great Desert of Africa. The region is practically rainless and the greater portion is quite devoid of vegetation, and is uninhabited even by nomad tribes. The extreme barrenness of the desert as a whole, however, is in great measure counterbalanced by a number of isolated, highly fertile oases, in which there is a permanent resident population. The chief groups of oases are the Siwan on the north, that of Kufra on the west, and the Egyptian, including the four large oases of Baharia, Farafra, Dakhla, and Kharga, on the east. The Egyptian oases occupy extensive depressions cut down nearly to sea level through the generally horizontal Cretaceous and Tertiary rocks forming the Lybian desert plateau. These depressions owe their origin in great measure to the differential effect of subaerial denudation acting on rock masses of varying hardness and composition.[b]

Description.—The suite contains some eighty-five representative specimens, ranging from simple rounded tablets to very involved intergrowths, and varying in size from three-fourths inch (19 mm.) to 2¾ inches (70 mm.) in diameter. They are composed of about equal percentages of quartz sand and the mineral barite or heavy spar, and in color and luster resemble maple sugar. Their surface has a fine-granular appearance because the rounded quartz grains protrude very slightly from the baritic cement. The only crystal face present is the basal plane *c* (001), which, however, is universally developed and controls the habit of every unit and compound.

The simplest form, which may be considered the fundamental one, since it enters into the makeup of every aggregate, is occasionally found in single development, as shown in figs. 1 and 4, plate 9. This is a flat crystal bounded above and below by basal planes and circular in outline with scalloped border. To one looking down upon an edge it has the appearance of being laminated or twinned parallel to the base, and possibly represents a serrate-edged group produced by

[a] A. Geike, Textbook of Geology, vol. 2, p. 1207.

[b] H. J. L. Beadnell, Flowing wells and subsurface water in Kharga Oasis. Geol. Mag., vol. 5, 1908, pp. 49–57; 102–108. For a very entertaining account of this oasis, which combines scientific accuracy with liveliness of portrayal, the reader is referred to a recently published book by the same author, entitled An Egyptian Oasis; an account of the Oasis of Kharga in the Lybian Desert. London, 1909.

the parallel growth of small plates. Its rounded contour is in all probability due to a concretionary tendency; that is to say, its imperfect crystal form is supposed to be the resultant of two molecular forces, the one striving for the formation of crystal outline, the other intent upon the development of concretionary structure, and each partly successful. In other words, the completion of the concretion was prevented by the development of two crystal planes—the very two planes, indeed, which in barite are potentially the most powerful, as evidenced by their universal occurrence and the perfect cleavage parallel to them. The tablet can not owe its rounded outline to the carving effect of wind-blown sand, for similar shapes are found in protected positions within complex groups, nor is there ever any sign of differential abrasion.

A second type, more complicated, is shown in figs. 2, 3, 6, and 7, where two or more plates similar to the one described above interpenetrate. There is universally a central tablet, to which the others are variously inclined, and the several components apparently possess a *b*-axis in common. Usually two oppositely-inclined plates (fig. 2) make angles of 30°[a] with a central one, though angles of 12° and 45° are not uncommon, and those of 65°, 70°, and even 90° (fig. 7) are occasionally met with. Many of these inclinations may be included in a single group; or by various permutations of two similarly inclined plates with one or more differently inclined even more complex assemblages may be formed.

Other still more involved growths have, in addition to plates crossing with *b*-axes in common, other plates variously inclined to these. The common disposition thus effected is shown in figs. 8 and 10, where three plates are inclined 30° to the base of a central plate, with angles of about 120° to 150° between their own planes. From above a three-sided, hopper-shaped appearance is presented. Evidently in such occurrences one or more of the plates fail to have even a single axis in common with the other plates possessing a mutual *b*-axis. Occasionally, too, a four-sided hopper is developed, as shown in figs. 9 and 11, where two of the secondarily inclined plates have opposite inclinations in respect to each other. Not infrequently the two patterns just described will be seen on the same specimen, the one on one side and the other on the other. Indeed, throughout the entire suite the two sides of the central tablet are almost invariably differently modified. Again, there are spherical skeleton forms, composed of many thin plates of nearly like diameter, resembling the rosettes from Rockenberg described by Delkeskamp.[b]

[a] The angles are only approximate, as exact measurements could not be made.
[b] Zeitschr. Naturw, Halle, vol. 75, 1902.

Upon the types described are frequently subsidiary growths, giving rise to strange and ungainly forms. An example is shown in fig. 13, where a slinder pile of small tablets has grown out at an angle from the main mass. There is evidently little regularity in the manner of attachment of these secondary members.

Symmetrical rosettes of the nature shown in fig. 5 are rare. Their regularity of structure is interesting. They are built up from a central plate by the piling around of other and smaller plates, with ever increasing inclinations to the central one, until the uppermost is nearly on edge. During their growth the *c*-axis of the consecutive individuals departs more and more from a vertical position, and the b-axis, so to speak, makes many complete revolutions in its several positions.

Fig. 12 represents the rare occurrence of two aggregates slightly intergrown. There are only two other cases of attachment in the entire suite.

An unusual radiate assemblage, composed of numerous elongated plates diverging from a center, is shown in fig. 14. This well illustrates the existence of two molecular forces of a somewhat different order, the one developing thin tables and the other uniting these in a common point.

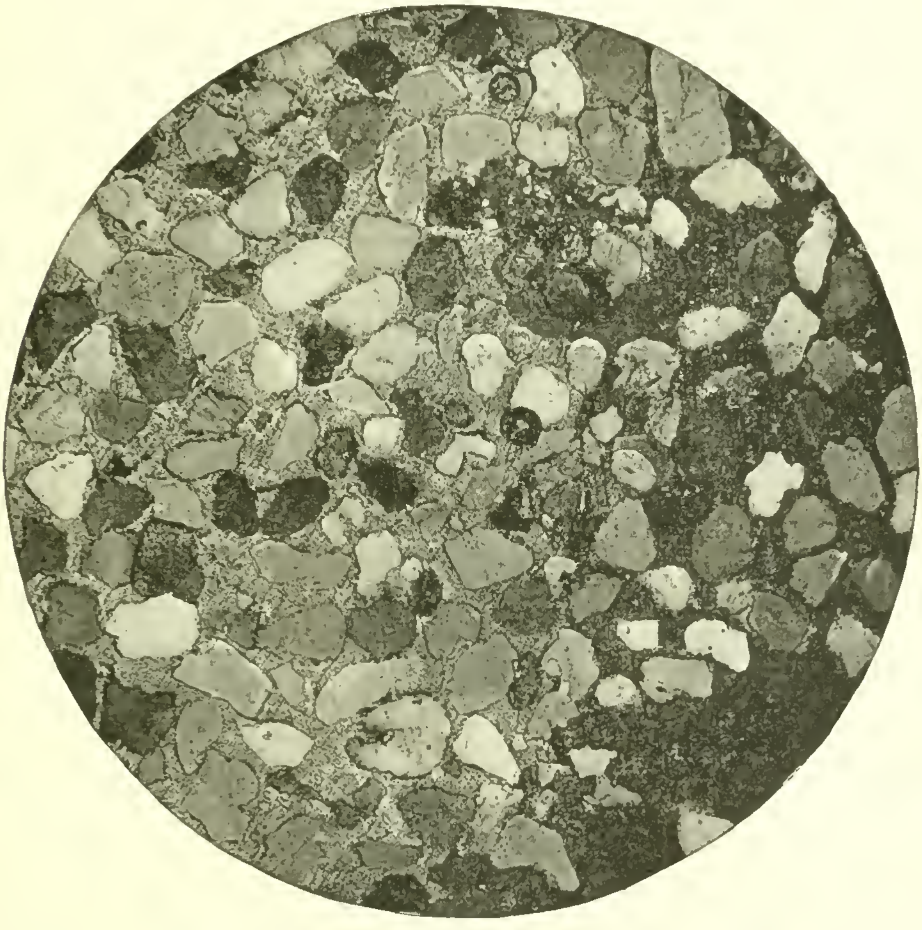
Finally, fig. 15 pictures a development represented only twice in the present collection and resembling some of the barites from Vilbel, Germany, as described by Delkeskamp.[a] This example consists of a thin, irregular sheet, with a surface of numerous globular masses, 2 to 5 mm. in diameter. It is entirely concretionary in nature (as the microscope also shows) and would seem to represent a case in which the crystallizing force was insufficient to inhibit a complete concretionary development.

Microscopic.—Several thin slices of the specimens were studied under the microscope. Three cases were considered:

1. Sections cut parallel to the basal plane, *c*. These show numerous rounded and some angular quartz grains, set in a cement of barite. The grains are usually from 0.25 to 0.5 mm. in diameter, and are rarely in contact with one another. The barite has the same orientation throughout, extinguishing simultaneously. It possesses two good cleavages parallel to the *m* (111) faces and crossing at angles of 78° and 102°; the more perfect basal cleavage is in the plane of the slide, and consequently not visible. A small amount of yellow, opaque, pulverulent limonite is present, either staining slightly the cleavage cracks of the barite and the edges of the quartz grains or forming small aggregates. No other constituents could be determined. The material is remarkably clean and pure.

[a] Zeitschr. Naturw, Halle, vol. 75, 1902.

2. Slide prepared at right angles to a penetration twin, a microphotograph of which is reproduced in the accompanying figure. The quartz presents the same features as in case 1. The barite, however, shows the perfect *c* or basal cleavage, dividing the mineral into long strips, with the less prominent *m* cleavages at right angles. There are two individuals, each of which extinguishes in polarized light as a unit, and has the same orientation of cleavage throughout. The extinction is parallel to the *c* cleavage, and the angle measured between the twinned parts is 30°.

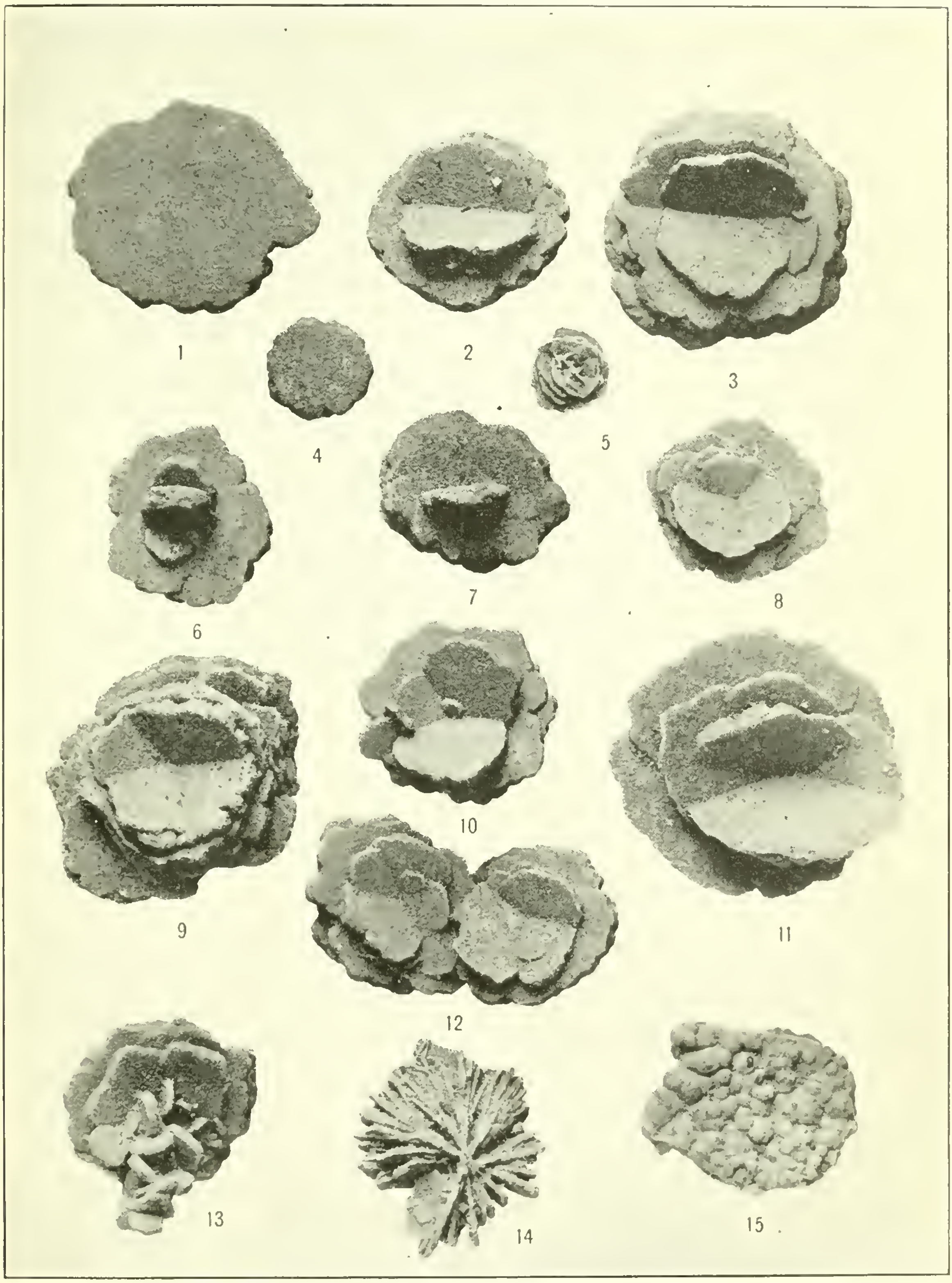


PHOTOMICROGRAPH OF A THIN SLICE OF SAND-BARITE, CUT AT RIGHT ANGLES TO A PENETRATION TWIN OF TWO TABULAR INDIVIDUALS CROSSING AT AN ANGLE OF 30°. POLARIZED LIGHT; MAGNIFICATION ABOUT 25 DIAMETERS. ROUNDED AND SLIGHTLY ANGULAR QUARTZ GRAINS ARE ABUNDANTLY INTERSPERSED IN A GROUND OF REGULARLY ORIENTED BARITE. THE INDIVIDUAL TO THE RIGHT IS NEARLY EXTINGUISHED, WHILE THE ONE TO THE LEFT IS BRIGHTLY ILLUMINATED. THE BASAL CLEAVAGE MAY BE SEEN IN EACH.

3. Cross-section of the concretionary specimen shown in fig. 15. In this the barite is without regular orientation of cleavage, and its extinction is undulatory. At no time during the revolution of the stage does the baritic matrix become dark. This example differs markedly, therefore, from the other instances in that the barite possesses no continuity of arrangement.

Chemical.—The percentage of sand in different specimens was found to vary. The limits are 44 and 53 per cent sand, with values between these figures. An average of five determinations for specific gravity gives 3.26. The silica content, calculated from this value, is 53.5 per cent.

Genesis.—The specimens were probably formed during the consolidation of the Nubian Sandstone in Upper Cretaceous or later time by the deposition from solution of barium sulphate in the interstices of a loose sand. The linear force of crystallization pushed the sand grains slightly apart, and the less well-understood power, which makes for an orderly molecular arrangement, developed an outer form in keeping with an inner structure.



REPRESENTATIVE SPECIMENS OF SAND-BARITE FROM KHARGA, EGYPT. ABOUT ½ NAT. SIZE.

FOR DETAILED DESCRIPTION SEE PAGES 20 TO 22.