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NEW METEORITE LOCALITIES IN THE RUB' AL KHALI, SAUDI ARABIA*

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ABSTRACT. Sixteen localities in the Rub' al Khali of southern Arabia are known to have produced meteoritic materials. Of these, only the centrally located al-Hadida has craters. The rest of the specimens must be assumed to have fallen as fragments of meteoritic showers. Many of the specimens are thoroughly oxidized, but several specimens of Ni-Fe metallic meteorites occur. Eight of the localities fall on a straight line oriented 300°. Others fall on either side of the line but not all at random. A selection of the specimens is being sent to the U. S. National Museum.

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Recent interest in outer space has stirred scientific curiosity in meteorites. Inquiries received within the past two years from Sears, Barnes, and Henderson, whose activities are well known to meteoriticists, have led to a re-examination of specimens, notes, and analyses in the files of the Exploration Department, Arabian American Oil Company, Dhahran, Saudi Arabia. Exploration field personnel have, since 1952, found and brought to the head office in Dhahran, specimens of exotic rocks, some of which, on chemical analysis, have probable meteoritic origins. Until May 1960, James B. Sheehan, a geologist on the staff, kept specimens and notes on meteoritic materials. After his departure from Aramco, the material was turned over to me, and the task of reporting on new finds was assigned to me by O. A. Seager, Assistant General Manager in charge of Exploration. Unfortunately, many specimens from al-Hadida (Wabar of Philby) and a few other finds were not obtained for the company collections but remain in the personal collections of several individuals who are no longer in the company. Since May 1960, however, a number of new finds have been reported or collected. This paper was presented in preliminary form before the meeting of the American Meteoritical Society in August 1960. The paper was revised to include some additional material in March 1961, and an additional revision was necessary in June 1961 to include still newer finds, as well as more information about some of the older discoveries.

RUB' AL KHALI

The Rub' al Khali is a great sandy desert in southeastern Arabia with an area of about 229,000 square miles. It was one of the blank spots on geographic maps, except for the explorations of Thomas (1932), Philby (1933a), and Thesiger (1945-1950), until the recent mapping of the region by Aramco.

At least sixteen localities are known in the Rub' al Khali where meteoritic materials have been found. Of these, three may be attributed to Philby (1933a) and one to Thomas (1932). Of the twelve remaining, we have specimens from eleven localities. In addition, there are probably one or two specimens in personal collections for which the localities are not known.

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TABLE 1

Meteorite localities in the Rub' al Khali

	Name	Discoverer	Latitude and Longitude	Type	Estimated Size
1.	al-Hadida	Philby	21°29'59.098"N 50°28'20.212"E	Ni-Fe* Glass* (**)	
2.	Naifah	Philby	19°58'N 50°46'E	Metallic	Small bean 8 gr
3.	"Umm Tina"	Philby	Indefinite	Stony	Small
4.	Buwah	Thomas	20°15'N 51°30'E	Chondrite	Small
5.	as-Sanam	Elberg	22°45'N 51°10'E	Stony*	20 x 20 x 15 cm
6.	ar-Rakhbah	Deeter	20°36'N 52°30'E		
7.	al-Jimshan	Deeter	20°42'N 52°50'E		
8.	South Dahna	Fraser	22°34'N 48°18'E	Ni-Fe* oxidized	275 kg
9.	Bir Hadi	Evens	19°25'N 51°02'E	Stony iron*	525 grams
10.	al-Ghanim 1	Evens	19°42'N 53°58'E	Stony*	780 grams
11.	al-Ghanim 2	Caudill and Kline	19°50'N 54°05'E	Ni-Fe* Metallic	Est. 500 grams
12.	as-Su 'aydan	McCue	21°15'15"N 55°18'18"E	Stony*	5.855 kg
13.	ad-Dahbubah	Gierhart	19°50'N 51°15'E	Stony*	Est. 200 pounds
14.	al-Ghanim 3	McCue	19°44'30"N 53°58'10"E	Stony*	Est. 1 kg
15.	al-Ghanim 4	McCue	19°40'50"N 53°59'35"E	Stony*	1.975 kg
16.	ash-Shalfah	McCue	21°52'30"N 49°43'10"E	Stony* weathered	935 grams

* Specimen available in Aramco collection, or in collection sent to U. S. National Museum.

(**) In collection of V. E. Barnes and U. S. National Museum.

THE DISCOVERY OF AL-HADIDA

When his guides led him to the site of al-Hadida. Philby thought he had at last come upon the ruins of the legendary city of Wabar. But as soon as he had a good look at the supposed ruins. he thought he was looking. instead. at the remains of a small volcano. Later, when he had had time to examine the ground and found the crater rims covered with pieces of glassy slag and many small spherical dark glassy beads, so-called "pearls of al-'Ad", and heard his men speak of a large piece of Hadid (iron), he urged them to find this iron. When they found it, he examined it and, noting how heavy it was. correctly concluded it was a meteorite. Disappointed in not finding the lost city of Wabar, he was consoled somewhat by having found hitherto unknown meteor craters, which are still quite rare in nature.

When Philby discovered the craters at al-Hadida in 1932. there were at least three and possibly four or five, visible. Sand is now encroaching from the north. and only one was still completely visible September 22. 1960, when V. E. Barnes and I flew down to collect specimens. A part of a crater rim to the northwest of the main crater was uncovered. By January 15, 1961, when I flew over al-Hadida to photograph it again. I could recognize only the main crater. The rest appeared to be covered.

Philby's sketch map (1933b, p. 180) shows the two largest craters aligned northwest-southeast, with the larger to the southeast. This had a diameter of about 100 meters and a depth inside the rim of no more than 12 meters. When Dr. Barnes and I were there, it appeared to me that five meters would be close to the depth visible, sand having filled in the floor. The second crater had a diameter of about 55 meters with depth less than that of the larger. The outer sides of the crater rims were covered with pieces and slabs of glassy slag.

Spencer (in Philby, 1933), gives a detailed description of the metallic meteorite Philby collected, as well as of the silica glass slag found on the crater rims.

After Philby, the next two western visitors to al-Hadida were Aramco geologists, T. F. Harriss and Walton Hoag, Jr., who reached it in late 1937. They verified his description of the craters, the presence of glass slag, and photographed the exposed craters (Harriss, Hoag, and Barger, 1938). They collected samples of slag bearing fragments of metallic iron. They thought a swarm of meteorites might have fallen, fusing the Neogene sandstones that underlie dunes in the area, rather than fusing the dune sands, indicating they assigned a pre-sand dune age to the fall.

METEORITE FINDS SINCE 1950

After the war, exploration in the Rub' al Khali began in 1950, and several field parties visited al-Hadida in ensuing years. E. L. Elberg, Jr., while carrying triangulation and levels through the region in 1952, located al-Hadida accurately, changing the coordinates as determined by Philby from Lat 21° 29′ 30″ N and Long 50° 40′ E to Lat 21° 29′ 59″ N and Long 50° 28′ 20″ E. Elberg collected pieces of metallic iron, glass slags, and a small quantity of glassy beads. He still has the latter in his possession. These include five pieces: 1) a button, concavo-convex, 2.25 cm in diameter; 2) four spherical beads, 0.9, 0.7, 0.3, and 0.1 cm in diameter. The beads are either smooth or with tiny protuberances.

In 1954, Elberg found several dark chunks of rock in the sands of as-Sanam (locality 5) and brought them to Dhahran. On analysis, this rock compares closely to the average of many stony meteorites. About the same time, Hans Helley, working further east, is reported to have found similar material. Unfortunately no data on the locality or analysis are available.

During the field season 1955, Wayne Deeter found two fragments of probable stony meteorite (localities 6 and 7) and told me that one of his Badawin drivers had brought him a third piece, for which the locality is unknown, although it undoubtedly came from the general vicinity of the other two.

In late 1957, H. B. Caudill and the late Robert D. Fraser found a large mass of dark ferruginous rock lying on a low sand dune in the southern part of the Dahna, near the eastern edge of the sand (locality 8) and west of the Summan plateau. James Sheehan sliced and polished a piece of this rock, etched it with nitric acid, and obtained Widmanstätten figures that suggest that it is of meteoritic origin. Chemical analysis showed the presence of mag-

TABLE 2

Meteorites from Rub' al Khali, Saudi Arabia—composition

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Fe	92%										87.3		1.6			
Fe_2O_3					33.4				49.6	33.2						
Fe_3O_4								87.5				34.0	36.0	39.6	36.5	
Ni	7.3										8.2					
NiO					1.8			5.6	2.3	Tr		Tr	1.4	0.9	1.3	
Co	X															
Cu	X															
SiO_2					37.1			0.2	8.6	37.2		37.3	33.3	33.3	35.1	
Al_2O_3					1.3											
MgO					23.4			1.0	20.7	21.9		25.0	23.3	19.5	20.4	
CaO					0.9			nil		1.9		2.4	1.7	2.5	2.3	
S									Tr							
Sp. Gr.	7.66				3.42			4.23	3.5	3.2	7.3	4.4	3.44	3.27	3.28	
Loss on Ignition					1.5			6.0	3.9	2.9		1.4	2.4	2.9	2.6	

netite and nickel. Fraser told me several months later that he thought there had been a large block of the material. The dimensions were rather vague, but the impression was that the block was large and too heavy to move. Caudill, when asked more recently, was less sure about there being a large block in place but said there were many pieces. In company with Harry Alter of Aramco, I visited the site in April 1961 and collected 380 pounds of the meteorite. It lay in a compact heap, broken into many pieces, none larger than 12.5 kg. It covered an area roughly 4 x 6 meters and 0.3 meter deep. It lay not on a dune but on a low platform of limestone about 0.3 to 0.5 meters above surrounding ground. It was partly covered by or lying in loose drift sand. The block appeared to have fallen in one piece and to have broken up because of weathering. The outer layers were foliated, lighter in weight. The central parts were dense and hard. The fragments were dark reddish brown to black, and some were coated in part by a green mineral which appears to bear nickel. It had been weathered and oxidized almost completely, although small metallic flakes could be seen on a sliced section. The material was slightly magnetic. No crater was observed in the surrounding region nor was any other meteoritic material observed. We estimate that the original piece fell as a nickel-iron meteorite, and that it weighed at least 275 kg.

In 1958, Joe Evens, head of a seismic party, found a piece of stony iron meteorite near Bir Hadi, a Badawin water well in the southern Rub' al Khali (locality 9). He gave it to R. D. Gierhart, who graciously turned it over to me in 1960. Bir Hadi lies about 75 km 160° from Naifah (locality 2), where Philby (1933b, p. 369) found a bean-sized metallic pellet.

In May 1960, Evens found several exotic pieces of rock in the southeastern Rub' al Khali in al-Ghanim area (locality 10). Two of these were obviously artifacts, but one was hematitic and appeared to have been exfoliated

from a larger piece. Its composition was similar to the average of stony meteorites listed by Clarke (1924, p. 40-44). Evens said that the material was fairly abundant but widely scattered. A request to the field party for more specimens arrived too late, as the party had moved to another location. However, H. B. Caudill and James Kline, on a reconnaissance trip shortly after, passed about 20 km northeast of Evens' locality 10, and found a piece of metallic meteorite the size of a child's fist and also collected what remained of the fall, from an area not more than a foot in diameter, partly buried in soft marl to a depth of several inches (locality 11). Back in camp, Caudill cleaned and polished the metallic piece with acid, removing the weathered film and exposing the metal. The other pieces, 25 in all, were turned over to me. One of these was metallic. The rest were like rusty iron flakes, but two on analysis proved to be oxides of iron and nickel. The metallic piece is pure Fe and Ni. No craters were found in the area.

John J. McCue, heeding my earnest plea, searched the area around his camp, and in December 14, 1960 found a piece of stony meteorite weighing 5.855 kg (locality 12). This is near the eastern limits of the sand in the Rub' al Khali. No crater was found. McCue re-examined the Ghanim area this spring and found two more specimens (localities 14 and 15), both stony. These were not large, weighing 1 and 2 kg. A short time after I had recovered the South Dahna meteorite far to the west, McCue was working near the northwest edge of the Rub' al Khali, and on a trip to ash-Shalfah (locality 16) found a much-weathered stony meteorite weighing 935 grams.

Gierhart and members of a seismic crew in March 1961 came upon a large block weighing an estimated 200 pounds, lying on the surface of a dune, northeast of Bir Hadi (locality 13). This proved to be a stony meteorite. It was in one piece when picked up but broke along existing cracks into several chunks ranging up to 90 pounds.

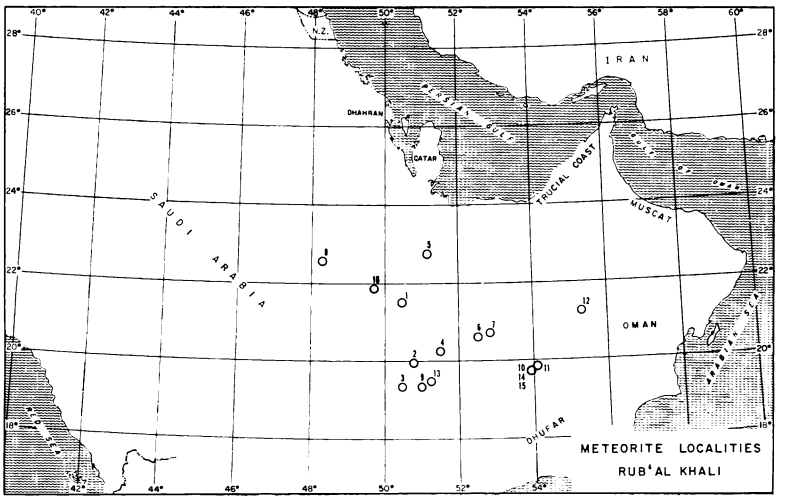

Fig. 1.

The specimens from localities 1, 6, 8, 10, 11, 14, 15, and 16, when plotted on a map of the Rub' al Khali, fall on a straight line, oriented 300°. Localities 2, 3, 4, 5, 7, and 12 fall on either side of this line (fig. 1). At present, we cannot say that all were part of a single meteorite shower as we have not examined many other parts of the Rub' al Khali closely.

RECENT COLLECTIONS FROM AL-HADIDA

Virgil E. Barnes and I visited the meteor crater at al-Hadida on September 22, 1960 to collect glass slag and to photograph the crater from the air. About 50 pounds of glass slag were collected, much of it lying about the surface of the sand in areas adjacent to the craters said to be northwest of the main crater and also on the rim of the main crater. The slag varied from tiny droplets, beads or rods, to chunks and slabs of vesicular glass large as a cabbage, some with partly fused sandstone attached. Only one fragment of metallic material was collected. It came from the rim of the main crater. The northwest crater was more than half covered by drifting sand and was not visible from the air. A photograph of the main crater from an airplane at low altitude on

Fig. 2. Aerial view of meteor crater at al-Hadida, central Rub' al-Khali, looking north of East. The crater lies in a vast area of low, rolling transverse dunes (zibar). The dark spots within the crater are desert shrubs. Photo by D. A. Holm, Aramco, September 22, 1960.

September 22, 1960 shows the rim and central hollow with low, rolling "zibar" sand ridges characteristic of as-Sanam lying to the north (fig. 2).

I flew over the crater of al-Hadida again on January 15, 1961 to take additional photographs in color, black and white, and in 16 mm cinema. At this time only the main crater could be distinguished from the air.

Dr. Barnes sent part of his glass slag collection to the U. S. National Museum. It was from this material that Dr. Chao and his colleagues of the U. S. Geological Survey determined the presence of the rare mineral *coesite*, which had been found previously in nature in the Meteor Crater in Arizona (Diablo), and at Rieskessel, Bavaria, Germany (Chao, Fahey, and Littler, 1961).

A representative selection of meteoritic materials in the collection described has been sent to the U. S. National Museum and a set of small specimens has been retained by the Exploration Department of Aramco, in Dhahran. Part of the Dahbubah and South Dahna specimens have been donated to the Geological Museum of King Sa'ud University, Riyadh, Saudi Arabia.

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