AL - HARRA'AT AND LIKE PHENOMENA IN SAUDI ARABIA AND YEMEN TERRITORIES

M.R. MOHAMMAD
Department of Geology, Faculty of Science,
Alexandria University, Moharram-Beh, Alexandria,
Egypt.

ABSTRACT

This paper deals with the planimetric shapes and areas of the occurrences forming Al-Harra'at and like phenomena, together with their distribution and orientation. The arabic name «Harra», «Harrah», or «Harrat», plural «Al-Harra'at» is refered to the nearly flat area covered by black to dark grey volcanic eruptions mostly of late Tertiary to Quaternary periods. They occupy a total area of about 101, 127.8 km^2 throughout the territories of Saudi Arabia and Yemen, concentrated mainly near the Red Sea coast. The axes of occurrences predominate by length and number in directions parallel to the axis of the Red Sea and in direction inclined by acute angels, up to about 40°, to the east and west of it.

The occurrences range, in planimetric area, from few to more than 20,000 km^2, accordingly they are classified into six size categories; huge occurrences of 10,000 km^2 and more), big (less than 10,000 to 5,000 km^2), medium (less than 5,000 to 1,000 km^2), small (less than 1,000 to 100 km^2), minor (less than 100 to 10 km^2), and the fine category (less than 10 km^2). Occurrences are also differentiated according to their planimetric shapes into three main types, longitudinal; in which the length is more than 3.5 times the breadth, rectangular; length between 1.5 and 3.5 times breadth, and equidimentional. Other two shapes, stellar and fan shaped, are also distinguished. Most of the occurrences belong to the rectangular type.

Two extensive areas of intensive regional Tertiary-Quaternary volcanic activity are outlined throughout Arabian Peninsula; one covering more than 66,000 km^2 in the provinces of Al-Madinah, Makkah, and Ha'il (Saudi Arabia), and the second spreading over more than 45,000 km^2 in northern Saudi Arabia and neighbouring countries.

Few occurrences are found within the extreme southwest of Saudi Arabia. Many occurrences are scattered through Northern Yemen and the western part of Southern Yemen. Along the Gulf of Aden coast, occurrences are concentrated within four areas from Bab El-Mandab until Jibal Assud to the east.

The areas of occurrences in Yemen territory as a whole do not exceed the medium size while those in Saudi Arabia reach up to the huge size.

INTRODUCTION

Volcanic activity in the Arabian Peninsula had increased through the Tertiary and Quaternary periods (Beydoun 1966, Brown 1970, and Coleman et al . 1970-75) covering vast areas especially in western parts of the peninsula near the Red Sea . Historic eruptions has also been reported in south western Syria, in western Saudi Arabia, in Yemen, and in Palestine . Tertiary and Quaternary eruptions constitute mostly Al-Harra'at and like phenomena in Saudi Arabia and Yemen (northern and southern) . About sixteen names of Al-Harra'at are written in the regional maps of the studied territories (Figs. 1 & 2), but too much local names are mentioned in the historical and geographical arabic books and dictionaries (Al-Andalusy 1947, Al-Hamawy 1956, Al-Balady 1978, Al-Qasir 1981 .. etc) in which more than eighty local names are mentioned just with their arbitrary locations . The same Harra may have more than one name and/or several names for each part of it in such publication.

Alkaline basaltic rocks, especially alkali olivine basalt, are the main constituents of Al-Harra'at and like phenomena (Coleman et al. 1970-75, Abed 1977, Al-Sayari and Zotle 1978), they are almost fresh to weakly altered dark fine grained volcanic rocks. The original rugged surfaces of eruptions are maintained in some exposures (Abo-Al-Haggag 1982).

This paper deals with general distribution, orientation, area, and shape of Al-Harra'at and like phenomena. The "like phenomena" comprise such occurrences that are similar to Al-Harra'at, as shown in the regional geologic maps, but are either nameless or with other names than "Harrah" The term "Al-Harra'at" will be used here as including such occurrences. Hundred and thirty nine occurrences are traced from the regional maps of the peninsula, mainly that of 1 : 2,000,000 (Brown and others 1963). They are numbered serially as shown in figures 1 & 2 and table 1. The leitz A.S.M. "Image Analysis System" is used for measuring the areas of occurrences.

DISTRIBUTION AND ORIENTATION

Al-Harra'at occur mostly in the western sector of the studied regions near the Red Sea coast (Figs. 1 & 2). Most of the bigger occurrences exist in

the basement complex of the Arabian shield especially of Saudi Arabia, of which about 79,000 km^2 are covered by Al-Harra'at.

This area represents about 83% from the sum area of Al-Harra'at in Saudi Arabia and Yemen. The rest 17% is scattered mainly through the northwestern and southeastern parts of the studied territories, where they overlay Eocene and Miocene sedimentary rocks (Brown and others 1963). Smaller occurrences are almost scattered around or between the bigger ones as in Saudi Arabia (Fig. 1), occasionally they are concentrated in separated areas like that of jabal Assud that contain 22 occurrences and jabal As-Sawda that contain 5 occurrences, both areas occur in Yemen territory (Fig. 2).

The central parts of the Arabian shield comprise vast areas of Al-Harra'at, (about 70% from the sum), forming occurrences more or less close together. They may have been originally bigger or even twice their present areas and most probably connected together. This indicates an intensive Tertiary-Quaternary volcanic activity in this sector which includes the regions of Al-Madinah, Makkah, and parts of Ha'il (Fig. 6). Arab historians reported also a volcanic historic eruption in the extreme northern part of Rahat Harra at the eastern part of Al-Madinah (P.1.1). This eruption took place during 1250 A.D. (Abed 1977). Another area of intensive Tertiary-Quaternary volcanic eruptions is that occupied by Al-Harrah; a huge occurrence covering the extreme northern part of Saudi Arabia (Fig. 6) and extending through Jordan (Abed 1982) and Syria (Al-Egl 1974) with a total area of more than 45,000 km^2. This Harra is shown in few regional maps (Sir Julian Huxley 1978) as extending also into western Iraq.

Most of Al-Harra'at are in the plan view of longitudinal and rectangular types (Fig. 7-a & -b) with their long axes parallel to subparallel to the axis of the Red Sea. The lengths and directions of eighteen principal axes (the longest axis of each occurrence(Figs. 1 & 2), are measured and plotted in azimuthal frequency diagrams (Fig. 3-a & -c). Average length of such axes is about 105 km. The linear trends developed by the arrangement of the volcanic peaks, plotted on the topographic and geologic maps of the peninsula inside Al-Harra'at, are considered as structural axes or lineaments (Figs. 1 & 2). Sixteen of such axes with average length of about 95 km are identified measured and plotted by the same way (Fig. 3-b & -c). Considering, as detected from the azimuthal diagrams of figure 3, that
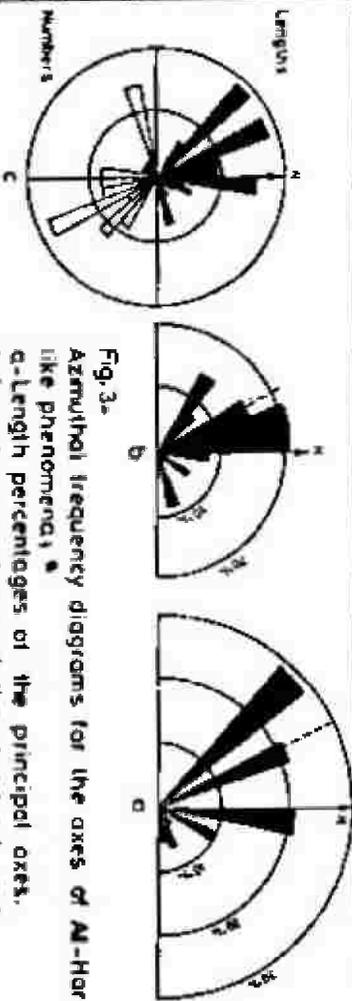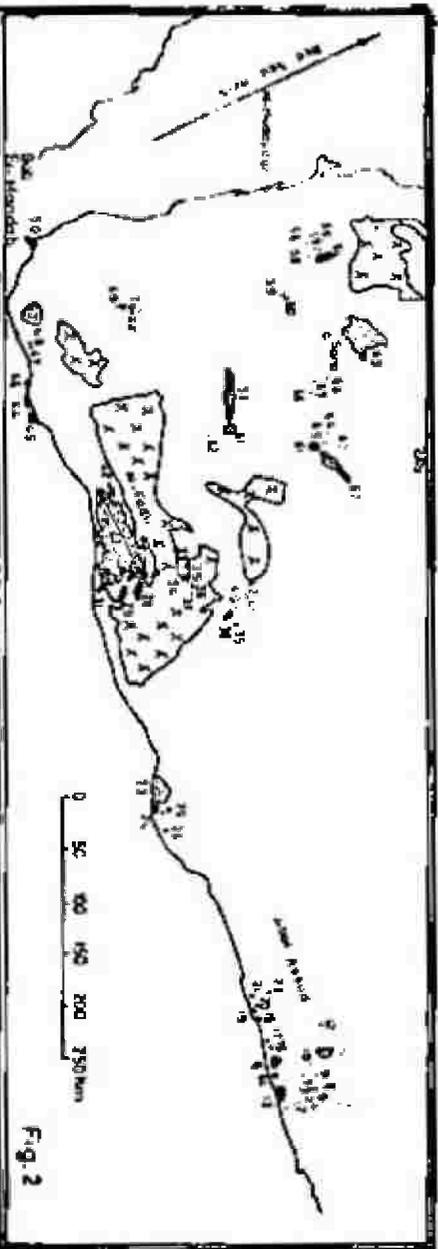
Figs. 1 & 2 *

Al-Harraat and like phenomena in Saudi Arabia (Fig.1) and in Yemen (Fig. 2 next page)

- Small occurrences
- Bigger occurrences
- Arabian shield
- Principal axes
- Structural axes

H - Abbreviation of Harrat

1,2,3..etc Ser. No. of Al-Harraat

* Compiled from the geologic maps of the Peninsula.

Axes and numbers are added by the writer

Fig. 3.- Azimuthal frequency diagrams for the axes of Al-Harrat and like phenomena; a
a- Length percentages of the principal axes.
b- Length percentages of the structural axes.
c- Length and number percentages of both principal and structural

Fig. 2

peaks of more than 10% may indicate local and/or regional significance, it is observed that :

a) Peaks of about 15% to 18% of length and number are developed parallel or nearly parallel to the axis of the Red Sea.

b) Peaks of about 15% to more than 20% are developed in directions (N-N 10°E) & (N-N 20°W) which are inclined to the axis of the Red Sea by acute angles up to 40°, or little more, to the east.

c) Peaks inclined to the west of the Red Sea axis, by acute angle up to about 32°, are developed in directions (N 40° - 50° W) with length percent of about 18% to 28% and in (N 50° - 60° W) with about 15% length percent.

d) A transverse number percent peak, approximately normal to the axis of the Red Sea, is developed in NEE direction (N 70° - 80°E) as shown in figure 3-c with smaller length percent peak, thus reflecting a relatively higher number of small elongated occurrences.

e. The two peaks: (N-N10°E) and (N 40° - 50°W) forming conjugate directions enclosing acute angle of maximum 60° around the axis of the Red Sea (Fig. 3-c), are characterized by larger length percent and smaller number percent, reflecting the few bigger occurrences in the studied territories.

These predominant directions emphasize the interdependence between Al-Harra'at volcanoes, which are mostly fissure eruptions, and the tectonic of the Red Sea. The axes of Al-Harra'at are almost parallel to inclined by acute angle (up to about 40°) to the east and west of the Red Sea axis which is trending approximately N 28° W. The structural axes are almost of much harmony with the Red Sea axis more than the principal axes.

AREA AND SHAPE

The areas of the hundred and thirty nine occurrences shown in figures 1 & 2 are measured, recorded in table 1, and plotted also in the columnar diagrams of figure 4. According to these areas, Al-Harra'at are classified into six size categories as follows :

1. Huge category, includes occurrences of 10,000 km² or more in area. It contains four occurrences in Saudi Arabia, their total area equals nearly 67% from the sum area of occurrences in the studied territories.

2. Big category, includes areas less than 10,000 km^2 to 5000 km^2, it contains two occurrences in Saudi Arabia, with total area of about 13% from the sum in the studied territories.

3. Medium category, includes areas less than 5000 km^2 to 1000 km^2.

4. Small category, of areas less than 1000 km^2 to 100 km^2.

5. Minor category, of areas less than 100 km^2 to 10 km^2.

6. Fine category, includes all the occurrences less than 10 km^2.

Total areas and number of occurrences of each category with their percentages are summarized in table 2 and plotted in the columnar frequency diagram of figure 5.

a) Area of Al-Harra'at in Saudi Arabia is much bigger than, about 15 times, that in Yemen. The huge and big categories appear only in Saudi Arabia, both together constitute about 80% by area from the sum in Saudi Arabia and Yemen territories.

b) The number of occurrences in each category is roughly inversely proportional to its area; few occurrences constitute the bigger categories (huge, big, and medium), while much occurrences constitute the smaller categories (small, minor, and fine).

c) The minor category comprise the highest number percent of occurrences. Minor and fine together constitute about 73% from the sum number in Saudi Arabia and Yemen.
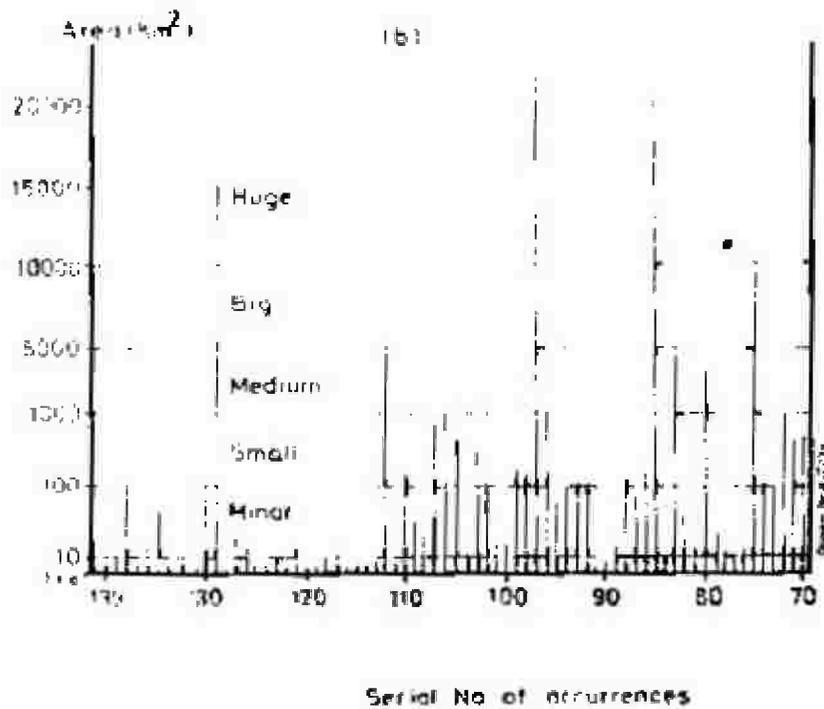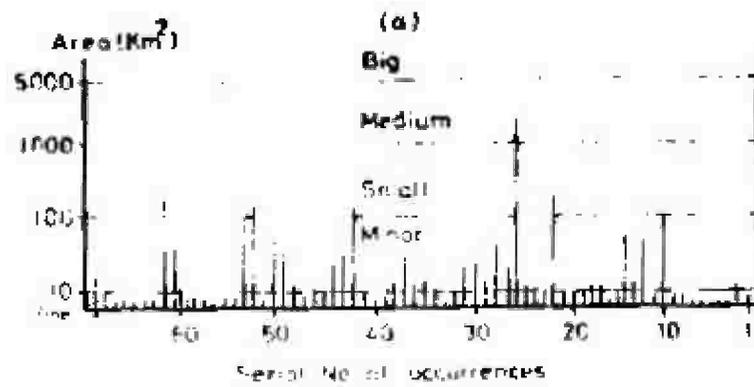
Fig. 4—
columnar diagrams showing the plan-metric areas of
occurrences in Yemen (a) and in Saudi Arabia (b) horizontal
lines separate the proposed size categories; huge, big,
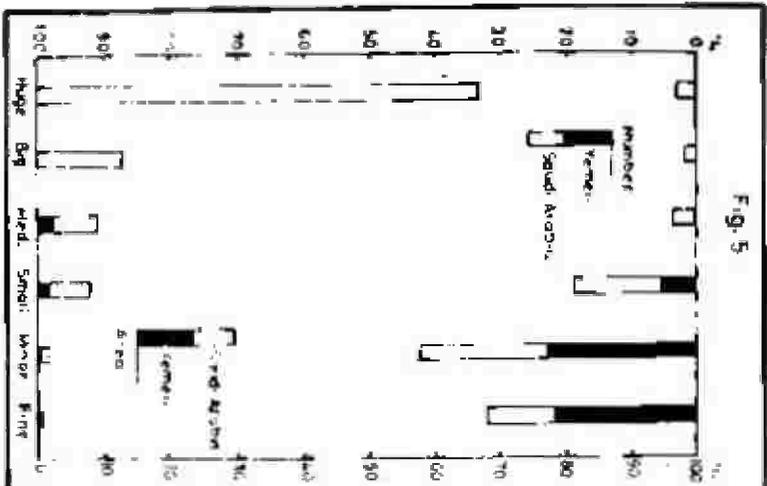medium, small, minor, and fine (each with different vertical scale)

Table 1

The areas of Al-Harra'at measured by "Leitz A.S.M." :

A. In Yemen territory

Serial number	Area km²	Ser. no.	Area km²	Ser. no.	Area km²	Ser. no.	Area km²/Ser.no.	Area km²
1	7.64	15	80.80	29	71.60	43	230.80/57	3.10
2	13.4	16	11.68	30	27.00	44	51.60/58	4.50
3	2.55	17	3.60	31	47.44	45	45.60/59	6.70
4	3.12	18	18.84	32	38.20	46	11.40/60	19.50
5	2.03	19	14.96	33	8.56	47	12.50/61	67.60
6	3.12	20	9.68	34	2.70	48	6.20/62	321.20
7	2.65	21	9.04	35	10.44	49	20.00/63	4.68
8	3.40	22	10.92	36	24.80	50	58.00/64	3.25
9	5.92	23	357.60	37	16.20	51	84.00/65	5.00
10	8.10	24	11.04	38	55.80	52	5.50/66	6.40
11	113.20	25	10.52	39	22.60	53	338.80/67	3.80
12	9.20	26	14.00	40	6.88	54	106 80/68	10.69
13	73.20	27	2664.00	41	4.80	55	6.30/69	850.40
14	22.76	28	40.00	42	9.36	56	7.10	

B. In Saudi Arabian territory :

Ser. no.	Area km²	Ser. no.	Area km²	Ser. no.	Area km²	Ser. no.	Area km²/Ser.no.	Area km²
70	689.00	84	13.24	98	280.00	112	7152.00/126	29.00
71	476.40	85	20240.80	99	311.20	113	9.00/127	37.70
72	1152.40	86	267.60	100	27.44	114	5.20/128	4.00
73	125.60	87	90.80	101	30.88	115	6.60/129	15227.60
74	120.80	88	176.8	102	121.20	116	4.20/130	194.68
75	10832.50	89	26.36	103	552.40	117	36.00/131	5.76
76	26.80	90	9.04	104	14.64	118	10.12/132	14.80
77	15.60	91	3.74	105	652.40	119	5.28/133	12.92
78	20.12	92	121.20	106	1165.84	120	5.60/134	74.00
79	44.00	93	125.60	107	853.20	121	25.00/135	25.88
80	3544.40	94	106.00	108	41.60	122	5.31/36	10.76
81	26.20	95	79.20	109	64.80	123	7.61/37	118.80
82	64.40	96	1056.40	110	269.60	124	8.72/138	15.60
83	6264.00	97	21662.20	111	44.80	125	7.64/139	113.60

Fig. 5

Fig. 6

Fig. 5 Columnar frequency diagram
showing percentages of total
number and total area of
occurrences in each size
category

Fig. 6 Regions of intensive Tertiary-
Quaternary volcanic activity
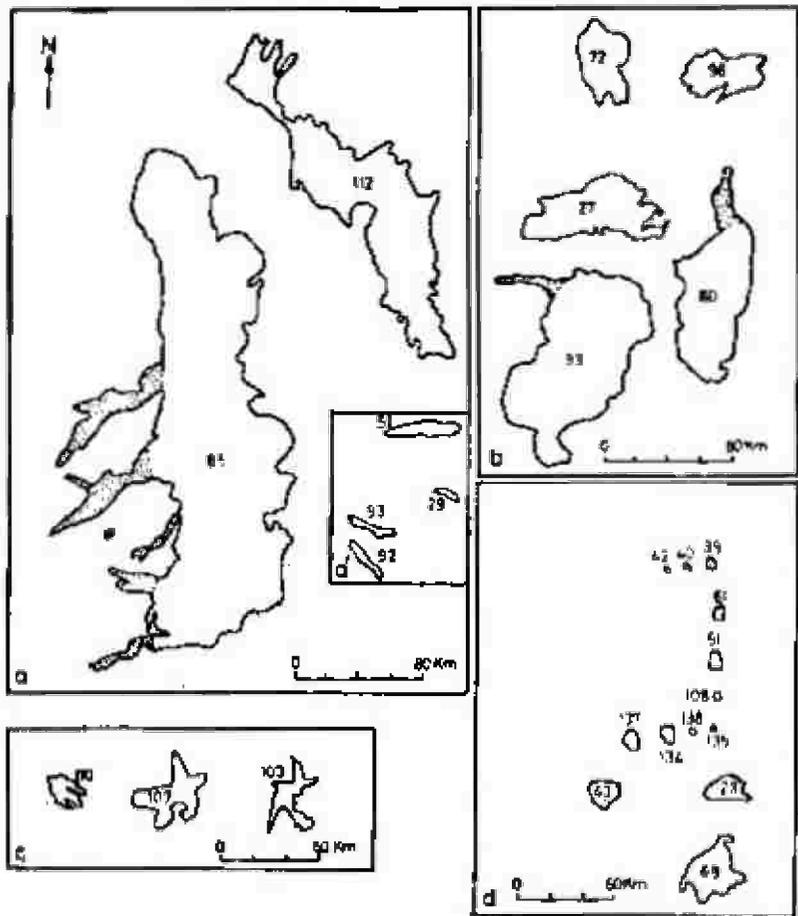in Arabian Peninsula outlined
by thick dashed lines

Fig. 7 –
Planimetric shapes of Al-Harraat and like phenomena; a & a′;
longitudinal, b, rectangular, c, stellar and fan shape, and d;
rounded to polygonal equidimentional. Side branches (stippled
parts), especially of the large occurrences, are not considered.
Each occurrence has its serial No as shown in Figs 1 & 2
and in Tab. 1.

Table 2

Classification of Al-Harra'at according to their planimetric areas shown in table 1 and fig. 4.

Category	Country	No. of Occurrences		Area of Categories	
		No.	Percent	Area (km²)	Percent
Huge	Saudia	4	2.9 %	67963.10	67.2 %
	Yemen	-	-	-	-
Big	Saudia	2	1.4 %	13416.00	13.26 %
	Yemem	-			
Medium	Saudia	4	2.9 %	6919.04	6.84 %
	Yemen	1	0.7 %	2664.00	2.63 %
Small	Saudia	19	13.7 %	5675.08	5.61 %
	Yemen	7	5.0 %	2318.80	2.31 %
Minor	Saudia	27	19.4 %	922.66	0.91 %
	Yemen	31	22.3 %	997.09	0.98 %
Fine	Saudia	14	10.1 %	87.68	0.10 %
	Yemen	30	21.6 %	164.36	0.16 %
Total	Saudia	70	50.4 %	94983.56	93.92 %
	Yemen	69	49.6 %	6144.25	6.08 %
Sum		139	100.0 %	101127.81	100.00 %

Al-Harra'at may also be classified according to their planimetric shapes into three principal types; longitudinal, rectangular, and equidimentional. The parameter for such types is considered to be L/B ratio, in which L represents the maximum length and B represents the approximate mean breadth of the occurrences. Transverse volcanic conspicuous branches, occasionally observed as extending from the big and huge occurrences, are disregarded when measuring B. It is proposed that the ratio L/B for the longitudinal type of occurrences should be more than 3.4, for the rectangular type; less than 1.5. The two variables; area and L/B are put in a

cross-tabulated contingency table (Table 3) The table is self-explanatory indicating that a- Most of the occurrences belong to the rectangular type. b. Smaller occurrences (fine, minor and small categories) tend to be of equidimentional and rectangular types, this is indicated by the large number of them in such types, c. Bigger occurrences (big and huge categories) tend to be of the rectangular and longitudinal types of shape.

Table 3

Cross-tabulated contingency table for area by L/B showing number of occurrences and their frequencies in the six categories of area.

L/B Area		Equidimentional less than 1.5	Rectangular 1.5-3.5	Longitudinal more than 3.5	Total
Fine	No.	16	28	0	44
	perc	36.4	33.3	0.0	31.7
Minor	No.	22	31	5	58
	perc.	50.5	36.9	45.5	41.7
Small	No.	5	17	4	26
	perc	11.4	20.2	36.3	18.7
Medium	No.	1	4	0	5
	perc	2.3	4.8	0.0	3.6
Big	No.	0	1	1	2
	perc.	0.0	3.6	9.1	2.9
Huge	No.	0	3	1	4
	perc.	0.0	3.6	9.1	2.9
Total	No.	44	84	11	139
	perc	100.0	100.1	100.0	100.0

Other shapes of Al-Harrat that may also be identified include the "fan shaped" which distinguishes one small occurrence in northwestern Saudi Arabia, and the Stellar or star shaped" which distinguishes, occassionally, a few of the small and medium size occurrences (Fig. 7-e).

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