Int. J. Econ. & Environ. Geol. Vol:1(1) 6-10

Volcanic Successions of the Jebal Remah Volcano, Northeast Jordan

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Abstract. Jebal Remah volcano is one of huge but very poorly known tephra cones exposed on the basalt province of Harra El-Jabban. Detailed investigations indicate that this volcano is topographically distinct and structurally well-developed. It consists of voluminous air-fall scoria, arranged in three distinct horizons; namely lower black lapilli horizon, middle banded yellow horizon and upper brown blocky horizon. Each horizon consists of friable, loose and well bedded ejecta. Agglutination and lithification are limited to the upper horizon. A comparison among the volcanic successions of three horizons show different volcanic features that nevertheless retain a comparable overall character from one horizon to another. In spite of some similarity in the type of ejecta, actually these differ in total thickness, number of beds and internal stratification. This dissimilarity within volcanic successions of the volcano support the overall increase in fluidity, temperature and decrease in volatile content of the magma with the time. Thus, volcano shows a complete range of thermal facies. The studied volcano appears to have resulted from one prolonged eruptive phase. Its volcanic activity consisted of a series of discrete explosion intervals, separated by quiet periods. Field criteria indicate that the volcano is of strombolian type of volcanicity and resulted in a magmatic fragmentation mode.

Introduction

Harra El-Jabban is the Jordanian part of the large inter-continental basalt terrain of Harra Ash Shamah, which covers an area of about 50,000 sq.km and lies in NW-Arabian plate (Fig.1). Harra El-Jabban has a vast areal extent of about 11,400 sq.km approximately 25% of the total area of Harra Ash Shamah and one tenth of Jordan's area (Al-Malabeh, 1994 a)_. This Harra consists of six basalt flows of Miocene-Holocene age. The last three flows of which are exposed. The volcanicity giving rise to the last flow was interrupted by an episode of eruptive activity of Pleistocene age producing large number of tephra cones. These volcanoes are distributed in chains that mainly have NNW-SSE or NW-SE directions. However, more than 30 cones occur in the Harra, which are distributed in two volcanic fields: Remah and Ashqaf in the western and eastern parts of the Harra, respectively (Al-Malabeh, 1994 b). These tephra cones have received very little attention. No comprehensive geological work has so far been published on these cones. Until now, their volcanic successions and their types of volcanicity are not precisely determined. Hence, very little is known about their relative ages. A detailed study of one of these tephra cones was thought to be relevant to illustrate the volcanic stratigraphy and phases of volcanicity.

Jebal Remah volcano was selected for this study because it represents one of the well distinguished examples of the cones, which are topographically distinct because of structurally well developed and positive relief in a vast plane area. This volcano represents one of the largest scoria cones in Harra El-Jabban and gives a good opportunity to study the successions of the volcanoes of the intra-plate type.

Jebal Remah volcano lies in the northern part of the Harra, about 15 km south of the Mafraq-Al-Safawi road, near Deer Al-Kaff village and 500 m south of the Syria-Jordan border (Fig. 1). Jebal Remah occupies an area of 4 sq. km.

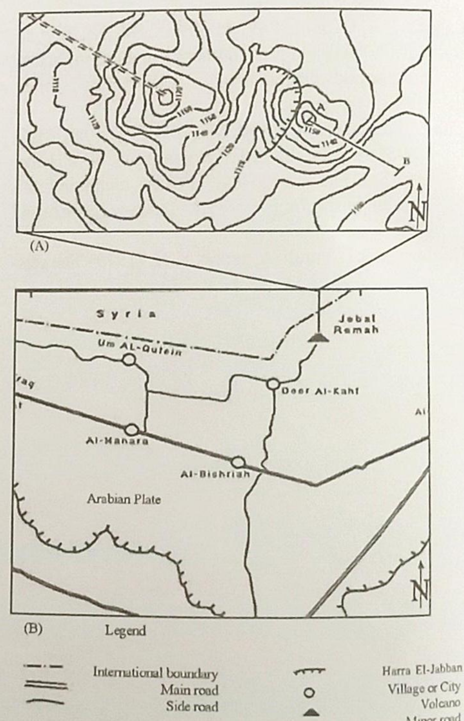

Fig. 1. Location map of Jebal Remah volcano.

It lies at latitude 32° 23′ 8" North and longitude 36° 55′ 42" East. Geomorphologically, the volcano shows two obvious summits, one to the east and the other to the west (Fig. 1). The overall shape of the volcano is elliptical, with long axis oriented N-S. The maximum elevation of the volcano is 1100 m above Sea level. The western part of the volcano is now extensively quarried, allowing a detailed investigation of its stratigraphy.

Volcanic Successions

Field investigations show that several eruptive episodes can be indentified within Jebal Remah volcano, which consist of limited variety of rock types and mainly made up of air-fall scoria. The ejecta are mostly lapilli and blocky shaped and form more than 95% of the total volume of the volcano. These deposits are commonly friable and loose, generally angular to subangular in shape and slightly to moderately vesiculated. The vesicles are rounded to subrounded and generally separated from each other by a thick wall. Agglutination and lithification are limited and welding is absent. Besides the pyroclastic rocks, one basaltic flow is recorded at the top of the succession. Moreover, varieties of xenoliths and accessory lithic fragments are occasionally observed. The most common stratigraphic feature is bedding. The rocks are normally arranged in beds that generally have constant thickness and show well developed planar stratification with little lateral variation. The beds in most cases are draped gently over each other. Remarkably, the beds are well sorted, but some of them exhibit different types of grading. Few internal structures like banding are also observed. Criteria include mainly erosion surfaces or millimeter thick oxidation zones or coherent basaltic flows. Other criteria such as color and size variations are also used to identify the bedding.

The volcanic succession of Jebal Remah volcano was studied in the eastern wall of the open mine along a vertical section occurring in the central part of the volcano (Fig.1). According to the size, variation and coloration, which are most important obvious volcanological properties, the succession of this volcano is subdivided into three horizons (Fig. 2).

The main characteristics of each horizon are summarized in Table 1.

- Upper horizon of brownish blocky deposits.
- Middle horizon of banded yellow lapilli deposits.
- Lower horizon of black lapilli deposits.

Lower Horizon of Black Lapilli Deposit

This horizon is mainly exposed in the lower parts of the open mine (Fig.1). The most important characteristics of this horizon are black to gray color of the ejecta and their lapilli are mostly about 2 cm in size. The exposed succession of this horizon consists of 19 beds and measures

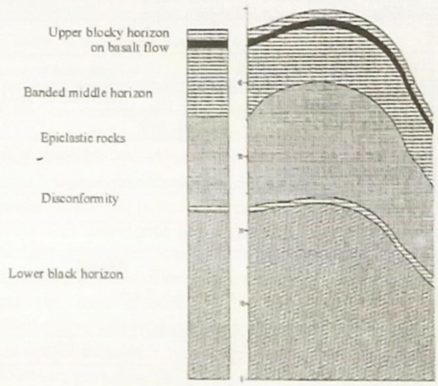

Fig. 2. Cross-section through the volcanic succession of Jebal Remah volcano (A-B in Fig. 1)

about 22 m in total thickness. The beds are generally well sorted, however, the upper most bed in this horizon is made up of badly sorted scoriaceous blocks ranging from 7 to 20 cm in size. Grading is very rare. One reversely graded bed of 190 cm thickness is recorded in the middle of the succession. Basaltic and scoriaceous bombs of diverse, but mostly spherical shapes (up to 40 cm. in diameter) are scattered randomly within the upper beds of this horizon, while the lower ones are seen to be bombs free. Some ultramafic xenoliths occur randomly within the beds, with diameter reaching up to 15 cm. Dunites, spinel and websterites are most common. Moreover, few accessory lithic fragments reaching up to 12 cm are also observed, which are of different varieties. However, quartzite, basalt and phosphatic rocks are the most abundant. The western part of this horizon is highly weathered. The vesicles of this ejecta are partially to completely filled with secondary minerals, particularly zeolites forming amygdales.

Middle Horizon of Banded Yellow Lapilli Deposits

A disconformity separates the middle horizon from the lower black lapilli horizon. The disconformity plane parallels a 2.5 m thick bed of epiclastic volcaniclastic rocks. This bed consists of reworked basaltic pyroclasts, in which angular to sub-angular dense and scoriaceous fragments as well as different types of accessory lithic fragments are embedded within a reddish ashy matrix (red tuff breccia). The fragments average up to 6 cm and some of them are green. It could be the result of insitu weathering of former pyroclastic rocks, indicating a long period of quiescence between the eruptions. However, the most distinguishing feature of the middle horizon is the banding of rocks, caused by the alternation of thin to thick black and yellow beds. Further, within the same bed, a well developed lamination is noted, in which yellow and black zones successively alternate.

The pyroclastic ejecta of this horizon are of lapilli with one centimeter as a dominant size. The horizon is bomb-

Table 1. Description of the main characteristics of different horizons of Jebal Remah

	Lower horizon	Middle horizon	Upper horizon
Type of pyroclastic rocks	dominated by scoria, air - fall deposits		
Bedding	well bedded, bedded planes sharply defined		
Color of ejecta	black gray	black and yellow	gray brown
Vesicles	very abundant and occur in the rock as a whole, spherical and elliptical are the most common shapes, elongated and irregular shapes also recorded		
Lithification	limited		
Welding	Absent		
Agglutination	Absent		Limited
Size range	lapilli ~ 2 cm	lapilli ~ 1 cm	blocky 7-40 cm and bearing ballistic bombs
Sorting	majority of the beds are well sorted		
Grading	reversely graded	symmetrically reversely graded	reversely graded
Lamination and banding	Absent	well recorded	Absent
Crystals	free crystal are totally absent		
Achneliths	few and mainly recorded on the flanks		
Xenoliths	mainly dunite, spinel, lherzolite and webstrite	mainly spinel, lherzolite and webstrite	Absent
Accessory lithic fragments	basalt, quartzite and phosphate	Limestone	Quartzite
Basalt flow	Absent		
Basalt dike	Absent		

free. A total of 17 constituent beds are counted, having a thickness of 14 m. However, total thickness of the yellow beds exceeds that of the black ones. The majority of beds, numbering fifteen, are well sorted. The remaining beds, numbering two, exhibit grading. One is symmetrically reversely graded and the other reversely graded. Xenoliths are abundant, but are generally smaller in numbers and size in comparison to those in the lower horizon. Varieties of spinel, lherzolites and websterite are common. Whereas, few sub-angular to rounded accessory lithic fragments of limestone and quartzite are recorded and scattered throughout the horizon.

In the yellow beds of this horizon, the lapilli are highly palagonitized. In hand specimen, the palagonite shows a resinous yellow color. Different degrees of palagonitization are recorded. However, remnants of original glass of black color are still observed. Palagonitization in this horizon are probably caused by the ground water circulation in the area and this assumption merits further petrographic and geochemical investigations.

Upper Horizon of Brownish Blocky Deposits

The horizon is seen in the field to overlie the lower two horizons from which it is distinguished by different lithological and stratigraphical features. It mainly consists of pyroclastic rock within block size range. The ejecta reflect a low degree of fragmentation. A total of 5 very thick (>150 cm) beds with well developed planer stratification are counted. The total thickness of this horizon is about 13 m (Table 2). The lower beds are brownish, while the upper beds are brownish to grayish.

The majority of beds, numbering four, are well sorted mixtures of blocks of different size and some fine lapillis. Only one reversely graded bed is recorded in the middle of the horizon. Three agglutinated scoriaceous zones occur in the middle part of the horizon, which are grayish in color within a brownish bed and have an average thickness of about 30 cm. The agglutination is not continuous laterally. This horizon is also characterized by the occurrence of meter sized (up to 2 m) basaltic bombs, which are scattered through out the horizon, but are most abundant in the lower parts. Very few accessory lithic fragments of quartzite of very small size are seen in the uppermost beds of this horizon. Xenoliths are absent and achneliths are few. An extrusive basalt flow of about 2 m thickness is recorded in the uppermost part of the horizon.

Results and Discussion

The volcanic succession of Jebal Remah is typically composed of air fall scoria. The ejecta possess features similar to those published on these types of clasts (Buller and McManus, 1973; Walker, 1973; Heiken, 1978). The ejecta of the volcano are mainly lapilli in the lower and middle horizons, mostly below 2.5 cm in size and blocky in the upper horizon. Therefore, the volcano is classified as cinder-blocky cone rather than cinder cone.

A comparison between different horizons of this volcano shows that they exhibit different features that nevertheless retain overall comparable characters from one horizon to another. Despite some similarity in the type of ejecta, actually they differ in total thickness, number of beds, internal stratification and other lithological characteristics, such as presence or absence of agglutination and basalt flows. The volcanic successions of the cone consist mainly of well-bedded sequences arranged in planar stratification. The parallel horizontal bedding reflects that the cone was formed on a uniform blanket topography. The bedding maintains a uniform thickness thus, it may be described as mantle bedding.

The pyroclastic rocks from the studied cone are similar in most respects to those of active volcanoes with observed Strombolian/Hawaiian activity such as Pacaya Guatemala (Heiken, 1974) and Northeast Crater of Mt. Etna, Italy. However, on the basis of the dimension and the degree of dispersal area, the actual area over which a pyroclastic deposit dispersed is small and approximates 6 km^2 (Walker, 1981). This type of eruption may be classified as Strombolian rather than Hawaiian. This may also be explained by the basaltic composition of the magma, which behaved more explosively than eruption of basalts of Hawaii island. However, the literature on Strombolian-Hawaiian type does not include many detailed descriptions of either eruption. The distinction between Hawaiian and Strombolian pyroclastic fall deposits was only tentatively defined by Walker (1973). The low dispersal areas indicate at low heights of the eruption columns. However, the Strombolian eruption column is less than 10 km (Wright, 1980). This proposed type of volcanicity is supported by different criteria, such as low degree of fragmentation, color of the ejecta and their oxidation state, moderate degree of vesiculation, agglutination, occurrence of ballistic clasts (large bombs) and the presence of achneliths.

The studied cone appears to have resulted from one prolonged eruptive phase. Their volcanic activity consisted of a series of discrete explosion intervals, separated by quiet periods. The repose period between two successive eruption intervals was variable from one horizon to another and even within the succession of the same horizon. The time space between each explosive interval producing the succession was relatively long as deduced from the existence of weathering surface, oxidation zone and other separation zones. The time gap between the lower and middle horizon was long enough to allow deposition of 2.5 m thick reworked tephra (red tuff ejecta). However, periods of quiescence in volcanoes may repeat over a time interval, as small as several days, or several weeks extending to several months or two or more years (Fisher and Schminke, 1984).

The duration of each explosive interval was not identical. Generally, it was long enough to eject a voluminous mass of pyroclastic materials, as seen by thickly bedded nature of the volcano and the vast quantities of scoria. The fluctuation in the interval duration is reflected by the variability in thickness of the beds. The factor governing this fluctuation is the mass ratio of solids to gas in individual explosions. However, the range in eruption duration in cinder cones is 1 day to 15 years with a median value of 30 days (Wood, 1980). Stromboli is characterized by periods of less than 0.1 seconds to several hours (Blackburn et al., 1976).

Table 2. Columnar section through the upper blocky horizon of Jebal Remah

Horizon	Legend	Clast Size (cm)	Thickness of bed (cm)	Description of deposit	Xenoliths	Lithics
Upper Blocky Horizon		10	260	well sorted	Not recorded	Very few Quartzites (small size 2 cm)
		-	200	basalt flow		
		1 - 20	200	well sorted		
		12	150	reversely graded		
		7 - 25	300	well sorted		
		5 - 12	200	well sorted		

The explosions varied in pattern from eruption to eruption and were not uniform within a single eruption phase. Fluctuation in the building intensity and explosion pattern is supported by different size of the fragments and the presence of graded beds. Increase in clasts size in successions of the volcano from lower and middle lapilli to upper blocky and the occurrence of relatively dense as well as large bombs at the top of the Jebal Remah succession, may reflect difference of explosion strength and increased coalescence of gas bubbles in the magma column, as eruption progresses. The occurrence of some beds that have different types of grading in the succession of the cone, indicate changes of conditions of eruption, producing either successively coarser or finer pyroclastic fragments. Based on the existence of agglutinated beds and effusion of lava flows, it is suggested that Jebal Remah had lower explosive strength and higher temperature gradients. However, a more powerful explosive activity is included in the lower and middle horizon of the Jebal deduced from the occurrence of mantle xenoliths. The uniformity of explosion strength and temperature gradients in the lower horizon is indicated by an overall comparable size range of the clasts and absence of agglutinated beds as well as basalt flows. However, minute fluctuation is demonstrated by the occurrence of some blocky and graded beds.

The scoria of the lower two horizons are commonly loose and friable compared to younger horizon of the same eruptive phase. This may reflect a low deposition temperature indicating that they were solidified in the air after expansion of the plume (fire fountain) and deposited cool on the earth under the influence of gravity. On the other hand, the occurrence of agglutinated zones in the upper horizon reflects the decrease in gas content of the magma near the end of the eruption, resulting in ejection from a lower eruption column of pastely spatter fragments, which retain enough heat to agglutinate together on landing. Frequently, the basalt effusion, particularly in the terminal stages, may reflect the complete degassing of the magma at the end of eruptions and gives an indication of waning explosivity with time. This dissimilarity within the volcanic successions of Jebal Remah volcano supports that the magma increased in fluidity and temperature and decrease in volatile content with time. Thus, the volcano shows thermal facies indicating overall up-section increase in temperature and reflects downward decrease in the volatile content of the magma chamber.

The fragmentation process in the investigated cone is thought to have resulted from magma eruptions. Sufficient parameters are available in their successions to justify this type of volcanicity, which are as follows.

1. Strombolian eruptions are magmatic eruption, defined for basaltic volcanism (Walker and Croasadle, 1972, Fisher and Schminke, 1984).

2. The low degree of fragmentation dominated by lapilli and blocky size,

3. The crystal-poor nature of the rocks.

These latter two characteristics mark the sustained eruption of a fluid and Newtonian magma, having low fines. The interaction of the parental magma with external water in the explosion activity is most unlikely. Water involvement is characteristics of phreatomagmatic eruptions, which are distinguished by high degree of fragmentation. The negligible occurrence of ash in the studied volcano confirms this interpretation.

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