Using Wind Data to Prediction the Risk of Volcanic Eruption. An Example of Damavand Volcano. Iran

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Abstract
Damavand is a large dormant stratovolcano in the Alborz Mountains of northern Iran located in one of the most populous provinces, which could be adversely affected by tephra fall from Damavand. The youngest known eruption is a lava flow on the western flanks with an age of 7.3 ka. The volcanic products are predominantly porphyritic trachyandesite. Three major young pumice deposits, named here as Mallar, Karam Poshteh and Reyneh pumices, are identified, with provisional ages in the interval >7.3 ka and < 25 ka. The deposits cover much of the southern and western flanks of the volcano. The Mallar and Reyneh deposits consist of extensive basal pumice fall deposits with dispersal axes to the east, overlying pumiceous pyroclastic flow deposits extending up to 20 km from the summit and late-stage lahar deposits. The middle unit (Karam Poshteh) consists of a coarse-grained pumice fall deposit with proximal welded facies dispersed to the west, but lacks pyroclastic flow deposits. Based on reconnaissance field data they were formed by explosive eruptions of VEI4. Some of the villages on the flanks of the volcano are built on pyroclastic flow and lahar fans, and thus would be at high risk in the event of future explosive eruptions. We present an analysis of wind data and the applications of a computer tephra dispersal model to assess tephra fall hazards. Explosive eruptions of Damavand in the future would adversely affect large cities in the neighbouring provinces to the east, reflecting the dominant regional stratospheric wind directions.

Key Word: *Damavand Volcano, Explosive Eruptions, Volcanic Hazards, Pyroclastic Units.*

1-Introduction
Damavand Volcano is the highest mountain (5670 m) in the Middle East and west Asia and is located 60 km to the ENE of Tehran (Fig 1) in Mazandaran Province. This provience is one of the most populous provinces by population density with diverse natural resources is also closed to the volcano. Many people live in four big cities and on the flanks of the volcano in hundreds of small towns and villages. Golestan and Semnan Provinces which also have large populations are two Volcano neighbors.

2-Previous study
Geology of Damavand have been studied by many researchers. Most studies concentrated on general geology, petrography, petrology and geochemistry of lavas and volcanic rocks. [1&2] did a systematic study on geology of Damavand and [5] did an important petrological and Geochemical study on volcanic and some pyroclastic rocks of Damavand. Geology of Damavand also studied in Few MSc and PhD theses. Knowledge on pyroclastic and volcano-sedimentary rock units of Damavand is quite limited and confined to reconnaissance study [3] and [6]. [3] described young pyroclastic deposits that they concluded were formed by sub-Plinian explosive eruptions.

Knowledge about the age and geochemistry was significantly enhanced by the study of [4]. This study showed that the volcanism goes back to at least 1 ma with on older sequence. The youngest known eruption is a lava flow on the western flanks with an age of 7.3 ka. [4] also confirmed that the largely volcanic products are remarkably uniform in composition and petrology, being predominantly porphyritic trachyandesite. Alkaline basalts of Damavand known as early stage of volcanism. They also showed that the trace element geochemistry has affinities with intraplate volcanism rather than subduction-related volcanism.

[7] Published the results of a reconnaissance study on stratigraphy of young pyroclastic deposits and an initial assessment of related hazards. Their new data indicate that the volcano has had high intensity explosive eruptions, producing widespread pyroclastic fall and flow deposits. [7] also describe the distribution and characteristics of three pyroclastic units and interpret them, in terms of eruption style, likely magnitude, and hazardous effects. They then discuss the current state of the volcano and the likelihood of the next explosive eruption and discuss possible scenarios and impacts of future eruptions locally and regionally. Their new evidence points to three major explosive eruptions in the recent geological past.

3-Pyroclastic units in Damavand

[7] study was identified three major pyroclastic deposits in the southern and western flanks of Damavand Volcano. The deposits were named after the most prominent localities and are, in stratigraphic order from oldest to youngest: Reyneh pumice deposits, Karam Poshteh pumice deposits, and Mallar pumice deposits. Reyneh pumice deposits are found in local valley fills from Mallar adjacent to the Gezaneh valley to valleys due west of the Damavand summit. Exposures have been found up to 20 km from the volcano's summit.

Reyneh pumice deposits consist of an amalgamated sequence of numerous thin pumice flows deposits with 0.5 to 2 metres thick and are commonly reversely graded and thin horizons of pumice fall deposits intercalated with the pumice flow deposits. These deposits are overlain in most localities by coarse-grained lithic-rich lahar deposits. Karam Poshteh pumice fall deposit is a young pumice fall deposit and distributed over much of the south-western and western flanks. Karam Poshteh pumice fall deposits can be usefully divided into thin more distal unconsolidated pumice fall deposits and up to 10 m thick proximal welded pumice fall deposits. Mallar pumice deposits are found in Gezaneh valley to the western flanks of the volcano and consist of basal pumice fall deposit which thinning and fining to the west. It also consist of pumice fall deposits which overlain by a series of pumice flow deposits. and flow deposits.

[7] suggest that the Reyneh deposits and to a lesser extent the Mallar deposits show evidence for pulsatory activity with intraformational pumice fall in the Reyneh and minor reworked horizons in the Mallar. The lack of intra-formational reworked deposits thus suggests periods of hours or days rather than months for the pauses.

4-Discussion

Patterns of activity at comparable stratovolcanoes, suggest that it is common for such volcanoes to have hundreds to thousands of years periods of dormancy prior to major explosive eruptions. Large explosive eruptions are commonly followed immediately by periods of enhanced lava flow of dome extrusion building up lava shields, lava cones or dome complexes. Such constructive activity then stops and a long period of dormancy then ensues before the next explosive eruption. The upper steep-sided cone of the young Damavand is the source of many young lava flows, so another lava eruption with limited or no hazardous consequences would not be a surprise. Given that Damavand has alternated between periods of lava extrusion and explosive eruptions and has had no eruptions for perhaps as long as a few thousand years, its behaviour could well conform to this common pattern.

Patterns of dispersal tephra and tephra fall in the cities and provinces neighbouring of Damavand is depend to wind direction and velocity. Wind data to be a useful tool to capture atmospheric circulation patterns in a particular region, even where sparse conventional observations are available. Atmospheric information, in particular wind data, is crucial in order to perform tephra dispersal simulations.

To understand the hazard, wind data between 1990- 2007 were analyzed. Meteorological stations that supply wind profiles at different altitudes are scarce throughout the study region. Due to this lack of information available, wind data from global datasets in Wayoming University was used. 17 pressure levels (at 1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20 and 10 hPa), cover more than 25 km above sea level. These pressure levels convert to height in meter then use in diagrams. Temporal resolution varies from monthly averages to sub-daily data, typically at the synoptic hours of 00, 06, 12 and 18 UTC. Both wind direction (provenance) and velocity for four atmospheric levels considering 17 consecutive years. The data shows tropospheric levels and the stratospheric ones and describe tephra diffusion in the atmosphere. The atmosphere is divided into horizontal layers characterized by uniform wind velocity and direction. Particles are transported by the wind specific to each layer; when they fall into a lower layer they are affected by different wind. This process continues until the particles reach the ground.

A. 5-Results

The pumice fall deposit is not present on the western flanks, so the observations suggest an easterly dispersal. Fig 2 show wind provenance for tropospheric and stratospheric levels (5-25 km) above sea level at Damavand volcano. And Fig 3 show wind velocity for tropospheric and stratospheric levels in summer and winter. Four data points per day in August, July and December in 1999 and 2007 are examined. Westerly winds are persistent throughout the year, especially at 15 km above sea level. Wind velocities are higher during December (winter months) reaching on average around 80 and 90 knot for 10 and 15 km above sea level respectively. In contrast during summer months the velocity drops to around 20 m/s in both cases. Fig show wind velocity for trapospheric and stratospheric levels (20 km to 25 km above sea level, at Damavand volcano. At 25 km above sea level, summer easterlies wind reach a maximum during July, with 15 m/s on average. Wind velocity during the winter is higher than summer mainly due to the winter polar vortex, that is originated by the hemispheric temperature gradient. The most prominent features in the stratospheric circulation are a westerly jet in the winter hemisphere and low velocity easterly jet in the summer hemisphere.

If Damavand moved into a state of unrest then a major explosive eruption is a plausible scenario that should be planned for. Here we consider the Mallar and Reyneh as the kind of likely eruptions then the hazards are easy to identify.

Tephra dispersal is dominantly towards the east in all seasons (Fig. 2). Communities around the southern and eastern flanks of the volcano are in high hazard. A significant environmental disruption will be occurred to the east of the volcano with the major cities of Mazandaran Province. The risk of the cities of Sari, Amol, Babol and Qaemshahr increases in the spring and early summer due to wind direction in trapospheric and stratospheric wind direction. The hazard in Tehran is low, because of the dominance of westerly tropospheric winds. However, Tehran could experience tephra fall for high columns and during the summer.

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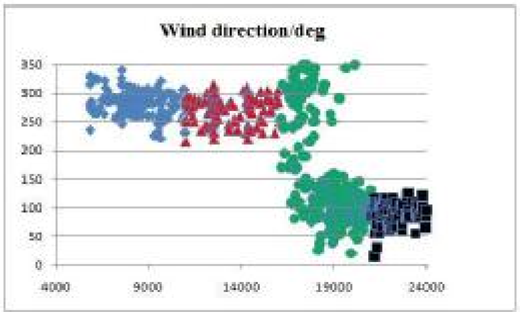
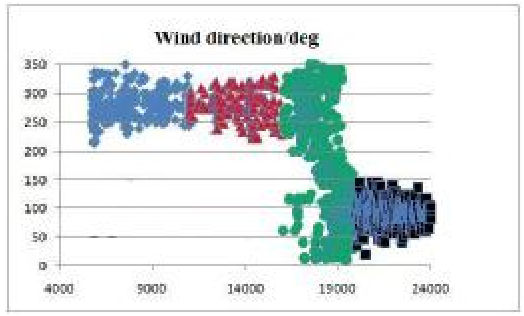
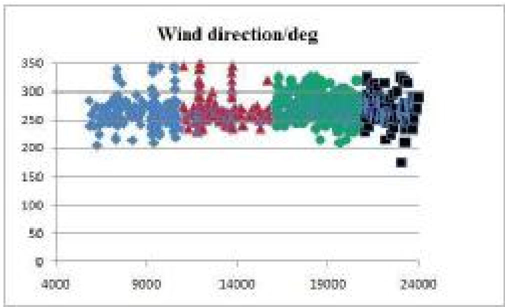
Figure 1. Satellite image of Alborz Mountains showing location of Damavand volcano located on the crest of the mountain range with Tehran to the west-south-west and the Caspian Sea to the north.



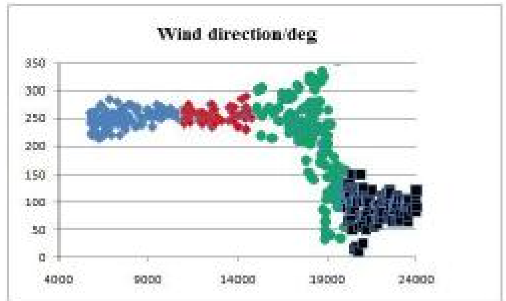
July 1999



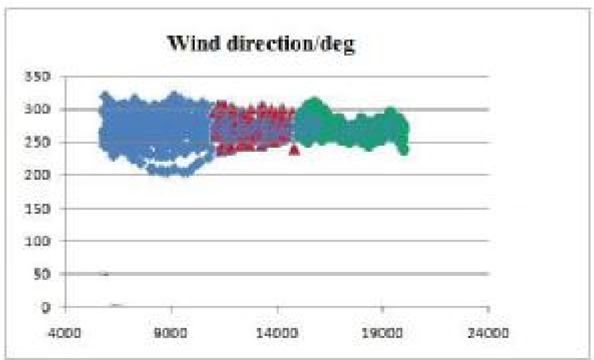
August 1999



December 1999

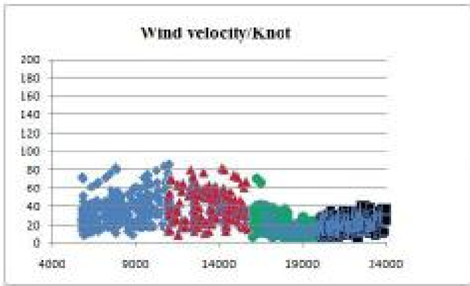


July 2007



December 2007

Fig 2. wind provenance for tropospheric and stratospheric levels in summer and winter.



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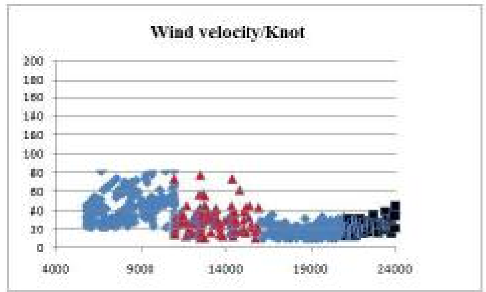

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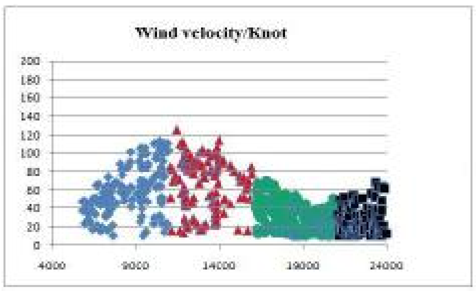
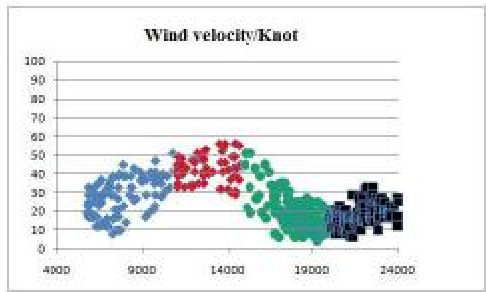
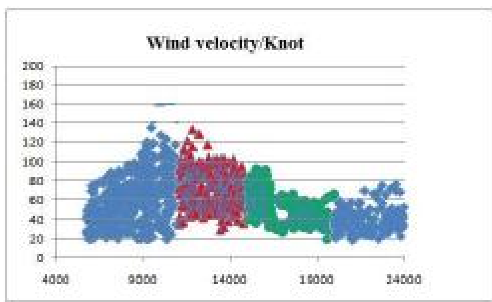


December 1999



July 2007



December 2007