Planetary and Space Science 57 (2009) 685–698

Contents lists available at ScienceDirect

Planetary and Space Science

journal homepage: www.elsevier.com/locate/pss

Geologic features of Wudalianchi volcanic field, northeastern China: Implications for Martian volcanology

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ARTICLE INFO

Article history:
Received 30 January 2008
Received in revised form
4 August 2008
Accepted 5 August 2008
Available online 15 August 2008

Keywords:
Volcanoes
Analogue
Wudalianchi
China
Ascraeus mons
Mars

ABSTRACT

Wudalianchi volcanic field, located in northeast China, consists of 14 Quaternary volcanoes with each volcano as a steep-sided scoria cone surrounded by gently sloping lava flows. Each cone is topped with a bowl-shaped or funnel-shaped crater. The volcanic cones are constructed by the accumulation of tephra and other ejecta. In this paper, their geologic features have been investigated and compared with some Martian volcanic features at Ascraeus Mons volcanoes observed on images obtained from High-Resolution Imaging Science Experiments (HiRISE), Mars Orbiter Camera (MOC), Context Imager (CTX) and Thermal Emission Imaging System (THEMIS). The results show that both Wudalianchi and Ascraeus Mons volcanoes are basaltic, share similar eruptive and geomorphologic features and eruptive styles, and have experienced multiple eruptive phases, in spite of the significant differences in their dimension and size. Both also show a variety of eruptive styles, such as fissure and central venting, tube-fed and channel-fed lava flows, and probably pyroclastic deposits. Three volcanic events are recognized at Ascraeus Mons, including an early phase of shield construction, a middle eruptive phase forming a low lava shield, and the last stage with aprons mantling both NE and SW flanks. We suggest that magma generation at both Wudalianchi and Ascraeus Mons might have been facilitated by an upwelling mantle plume or upwelling of asthenospheric mantle, and a deep-seated fault zone might have controlled magma emplacement and subsequent eruptions in Ascraeus Mons as observed in the Wudalianchi field, where the volcanoes are constructed along the northeast-striking faults. Fumarolic cones produced by water/magma interaction at the Wudalianchi volcanic field may also serve as an analogue for the pseudocraters identified at Isidis and Cerberus Planitia on Mars, suggesting existence of frozen water in the ground on Mars during Martian volcanic eruptions.

1. Introduction

The study of terrestrial analogues for Martian geomorphologic and geological features is important in understanding planetary processes on both Mars and the Earth. Hawaiian volcanoes (Greeley, 1973), Icelandic volcanoes (Tuffen et al., 2002; Fagents and Thordaeson, 2006), volcanic fields in New Mexico (Crumpler et al., 2006), and several continental flood basalt provinces (Greeley and King, 1977; Mahoney and Coffin, 1997; Keszthelyi et al., 2000; Keszthelyi and McEwen, 2006) have been used as the analogues. Studies of geomorphologic volcanic features and evidence based on recent remote sensing data on Mars suggest that Martian volcanoes are generally basaltic (Bandfield, 2002; Bandfield et al., 2000, 2003; Christensen et al., 2003, 2004a; Bibring et al., 2005; Rogers and Christensen, 2003, 2007), and Martian central volcanism style is most likely associated with a mantle plume (Mege and Masson, 1996; Harder and Christensen, 1996; Zhong and Robert, 2004). Spohn et al. (2001) analyzed data collected through Mars Global Surveyor (MGS) and Mars Pathfinder missions, models of Martian mantle convection and thermal history, and Martian meteorite chemistry data, and proposed that mantle plumes may have waned out with time as the Martian core cooled and mantle plume activity eventually phased out by the end of the Noachian.

Theoretical modeling and image interpretation also demonstrate that volcanism on Mars may have different eruptive behavior from its terrestrial counterparts. The difference is due to the lower gravity, and slower fluid convective motions and crystal settling processes driven by positive and negative buoyant forces on Mars (Wilson and Head, 1994a). Previous studies have identified a diversity of eruption styles on Mars. A well-studied example is Arsia Mons (Mouginis-Mark, 2002, 2003; Mouginis-Mark and Christensen, 2005). Other volcanoes such as Ascraeus Mons and Olympus Montes also show various effusive styles (Bleacher et al., 2007).

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doi:10.1016/j.pss.2008.08.005

Other volcanism-related geomorphologic features are also of importance in deciphering eruption environment and atmosphere and ground conditions because atmosphere air pressure may affect eruption styles (Sparks, 1978; Wilson et al., 1982) and groundwater and/or ice in regolith could cause magma–water interaction. For example, when lavas flood over water-saturated substrata or permafrost, water could be vaporized and erupt out of lava flows, leaving fumarolic, crater-like cone-shaped features or so-called "pseudocraters" as identified in some Icelandic volcanic fields. A number of workers have suggested that similar pseudocraters may also exist on Mars (Allen, 1979; Mouginis-Mark et al., 1982, 1988; Mouginis-Mark, 1985; Greeley and Crown, 1990; Crown and Greeley, 1993; Chapman et al., 2000; Greeley and Fagents, 2001; Lanagan et al., 2001).

This paper reports the first attempt to locate a terrestrial analogue in China. It focuses on the Wudalianchi volcanic field (48.72°N, 126.12°E; Fig. 1), which is located in north Dedu County of Heilongjiang Province of northeast China. Wudalianchi in Chinese means "five big connected pools" (i.e. lakes). At Wudalianchi several lava flows dammed the Bei River forming five lakes. These lakes are named Pool 1, Pool 2, Pool 3, Pool 4, and Pool 5, from north to south (Fig. 1). Bei River is a tributary of the Nemor River on the western flank of the Lesser Khingan Mountains in northern Heilongjiang Province. Geologically, the volcanic field is situated on the northeast margin of the giant Songliao Basin that hosts China's largest oilfield, the Daqing Oilfield. The Wudalianchi field consists of 14 volcanic cones that form two northeast-trending groups. It is one of the best-known recently active volcanic fields in Asia (Feng et al., 1979; Feng, 1982; Feng and Whitford-Stark, 1986; Whitford-Stark, 1987; Qiu, 1991; Simkin and Siebert, 1994; Wei et al., 2003) and is an UNESCO World Heritage Location (http://www.volcanolive.com/wudalianchi.htm) due to its spectacular volcanic landscape. Wudalianchi volcanic field showcases the best-preserved eruptive and geomorphologic volcanic features in China. For example, the volcanic features produced by the last eruption that was only less than 300 years ago are well exposed with little vegetation cover. The volcanic field is also well-known for the rare but best-preserved fumarolic cones in China (and probably in Asia).

In this paper, the Wudalianchi volcanic field is used as a terrestrial analogue to Martian volcanology, including volcanic features of Ascraeus Mons volcano and the suspected pseudocraters

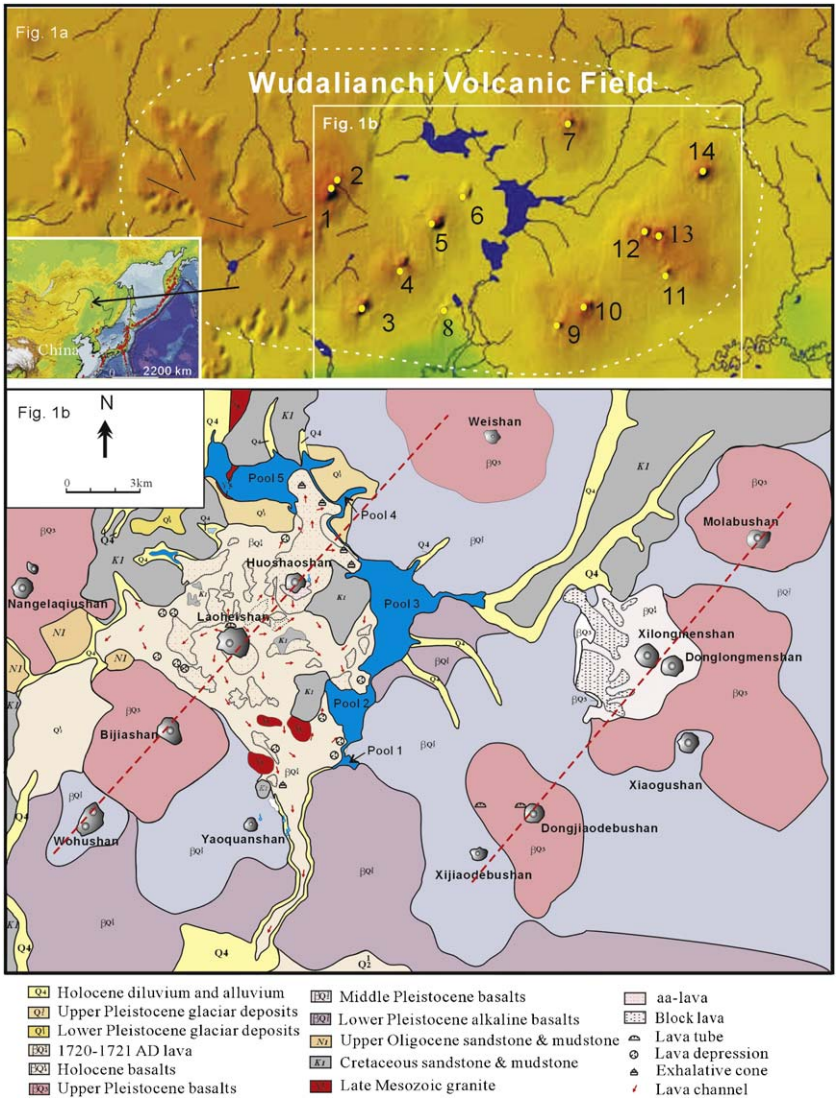

Fig. 1. Digital elevation model (a) and geological map (b) (modified after Feng, 1979) of the Wudalianchi volcanic field. Volcanoes are labeled with numbers: (1) Nangelaqiushan; (2) Beigelaqiushan; (3) Wohushan; (4) Bijiashan; (5) Laoheishan; (6) Huoshaoshan; (7) Weishan; (8) Yaoquanshan; (9) Xijiaodebushan; (10) Dongjiaodebushan; (11) Xilongmenshan; (12) Donglongmenshan; (13) Molabushan; (14) Xiaogushan. The field is about 2000 km away from the Japanese magmatic arc. Arrows in Fig. 1(b) indicate lava flow directions of Huoshaoshan and Laoheishan volcanoes.