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Occurrences of rock-fulgurites associated with steel pylons of the overhead electric transmission line at Tor Zawar, Ziarat District and Jang Tor Ghar, Muslim Bagh, Pakistan

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Abstract: We here report 3 occurrences of rock fulgurites: 2 at Tor Zawar, Ziarat District, and 1 at Jang Tor Ghar, Muslim Bagh, Pakistan. The first and second melting events occurred at Tor Zawar, Ziarat on 27 January 2010, and sometime during the month of January 2011; the third melting event occurred on 12 February 2011. All these events occurred near the base of steel pylons of electric transmission lines installed on hillside outcrops, which transmitted atmospheric lightning to the outcrop. At Tor Zawar, Ziarat District, the pylons are installed on outcrops of the volcanogenic conglomerate of the Late Cretaceous Bibai Formation, whereas, in the Jang Tor Ghar, Muslim Bagh, they are constructed on alluvium mostly comprising ultramafic fragments of the Muslim Bagh Ophiolites. The lightning strikes transmitted enough energy to partially melt the outcrops near the bases of the steel pylons. The melt solidified to produce light brown to black vesicular basaltic glass that is partly devitrified.

Key words: Rock fulgurites, extrusion, flow structures, basaltic and ultramafic host rock

1. Introduction

When lightning strikes the ground it heats, melts, and fuses the sand, soils, and rock outcrops to form glassy tubes known as fulgurites. They are also created when a grounding mechanism, such as a pylon, is struck by lightning and energy is channelled and dissipated into the ground, melting the soil or rock. The atmospheric lightning is a transient high current electric discharge that dissipates ~109 J per flash (Uman and Krider 1989) and occurs at a rate of ~65 lightning flashes per second worldwide (Mackerras et al. 1998). Fulgurites have been broadly classified as sand-type, comprising hollow tubes of fused sand grains where lightning struck dunes or beach sand (Anderson 1925; Petty 1936; Galliot 1980; Mohling 2004); and rock-type, typified as a thin fusion crust of glass with or without tubules, where lightning struck rock outcrops (Purdom 1966; Libby 1986). A more detailed classification was provided by Pasek et al. (2012), who distinguished 4 main types of fulgurites (type I are sand fulgurite; type II are clay fulgurites; type III are caliche fulgurites, and type IV are rock fulgurites) representing the variation in fulgurite morphology depending on substrate chemistry and texture. Most of the specimens of fulgurites are lustrous black glass, but fulgurites of other colours may be present. A number of artificial (accidental) fulgurites have also formed after high voltage cables fell on the earth's surface (Petty 1936; Fenner 1949; Raeside 1968; Bhattacharyya et al. 2002; Brandstätter et al. 2009). Brandstätter et al. (2009) used the term pseudofulgurite for this type of phenomenon. Williams and Johnson (1980) suggested that the formation of fulgurites in nature is similar to that of a high voltage discharge through a conducting powder. The predominant current-carrying element of a lightning discharge is the return stroke, which travels from ground to cloud following the initiating leader from cloud to ground (Uman & Krider 1989). The heat input of the return stroke can raise the channel temperature to as much as 30,000 K, more than enough to fuse and vaporise the rock surface (Frondel 1962). Lightning, when strikes the outcrop, has enough energy to heat and partially melt rocks of even basaltic composition. The formation of fulgurites may result in explosive extrusions of molten rock (Manimaran et al. 2001; Bhattacharyya et al. 2002; Pasek et al. 2012). Martin-Crespo et al. (2009) reported indications of magmatic flow in a fulgurite from Portugal, but formation of flow structures in larger volumes of molten rock has so far not been reported. Here we present 3 occurrences of fulgurites, which formed at the bases of

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steel pylons of electric transmission lines. The first melting event has been extruded and exhibits flow structures; and it has earlier been taken to represent the eruption of basaltic lava, although the total volume of molten rock is very small (Kerr et al. 2010a).

2. Occurrence of rock fulgurites

This study includes 3 rock fulgurites located at Tor Zawar Mountain (30°28.74N and 67°29.49E), Ziarat District, and Jang Tor Ghar, Muslim Bagh (30°44.91N and 67°43.74E), Pakistan, within the western Sulaiman Fold-Thrust Belt and Muslim Bagh Ophiolites (Figure 1); all were related to incidents of lightning strikes on the steel pylons of electric transmission lines. The first melting event occurred on 27 January 2010, the second sometime during the month of January 2011, and the third on 12 February 2011 (Figures 2–4). The first 2 occurred at the hillside outcrop of a volcanogenic conglomerate of the Late Cretaceous Bibai Formation, Western Sulaiman Fold-Thrust Belt, east of the Tethyan suture zone of the Eurasian and Indian plates (Bender & Raza 1995), whereas the third occurred at the Jang Tor Ghar, Muslim Bagh, within the alluvium, comprising mostly ultramafic fragments of the Muslim Bagh Ophiolites.

Rana and Akhtar (2010) and Kerr et al. (2010a) discussed the regional and local geology, volcanological aspects, petrography, and major and trace elements analyses of 2 samples of the first incident, and put forward their views regarding its possible origin. They state that "the incident produced a small volume (covered area: 8.2 m × 1.9 m; thickness: 0.15–0.6 m) of gas-rich, basaltic glass at Tor Zawar Mountain, Ziarat District, 75 km NW of Quetta". The other 2 melting events that we report are of similar nature but of smaller magnitude and lateral extent (<1 m^3). They occurred after the publication of Rana and Akhtar (2010) and Kerr et al. (2010a). However, the exact date and time of the second melting event of the Tor Zawar, Ziarat, is not known as it occurred unnoticed by inhabitants of the nearby village; they think it occurred sometime during January 2011. It occurred ~300 m north of the first incident.

3. Regional geology

The first and second melting events occurred within the outcrops of the volcanogenic conglomerate of the Late Cretaceous Bibai Formation (Kazmi 1979; Khan et al. 2000; Kassi et al. 2009) of the western Sulaiman Fold-Thrust Belt, which comprises mostly sedimentary successions (Figure 1; Table 1) of Triassic through Pleistocene age (Hunting

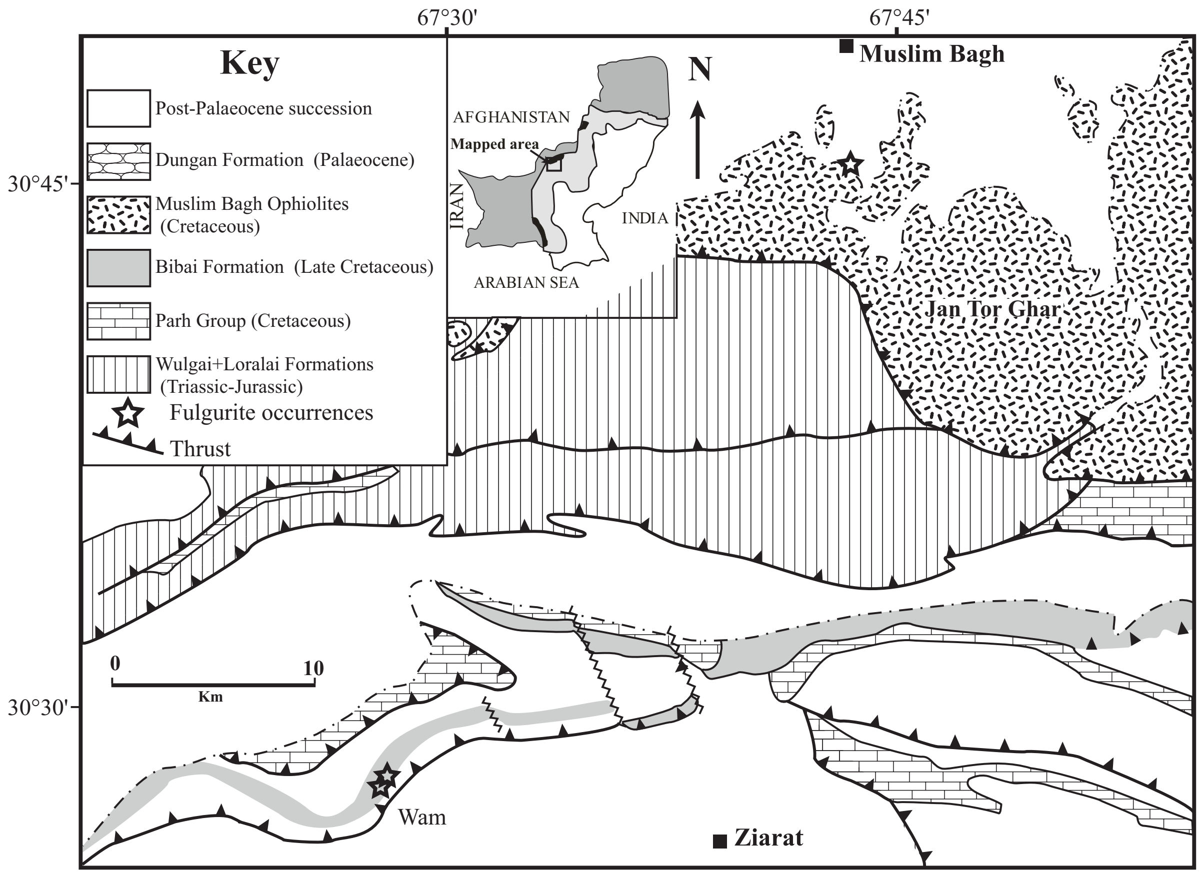

Figure 1. Geological map of the area showing positions of occurrences of the rock fulgurites.

Table 1. Stratigraphic succession of the western Sulaiman Fold-Thrust Belt.

Age	Formation	Lithology
Pleistocene	Lei Conglomerate	Conglomerate and sandstone.
Miocene–Pleistocene	Siwalik Group	Sandstone, claystone, and conglomerate.
Angular Unconformity		
Middle–Late Eocene	Spintangi Formation	Limestone, shale, and sandstone.
Early Eocene	Ghazij Formation	Claystone, sandstone, conglomerate, limestone, and coal seams.
Palaeocene	Dungan Formation	Limestone and shale.
Late Cretaceous	Pab Formation/Moro Formation/Fort Munro Formation/Oxidised Transitional Succession/ Hanna Lake limestone/Bibai Formation	Sandstone, siltstone, shale, limestone, in situ basic volcanic rocks, volcanic conglomerate, volcanic breccia, and mudstone.
Early–Middle Cretaceous	Parh Limestone/Goru Formation/Sembar Formation	Limestone (bio-micritic), marl, and shale.
Disconformity		
Jurassic	Shirinab Formation	Limestone and minor shale.
Triassic	Wulgai Formation	Shale and limestone.
Base not exposed		

Figure 2. (a) Photograph of the thick succession of volcanogenic conglomerates of the Babai Formation (in the background) forming the foundation of the steel pylons supporting the electric supply lines across Tor Zawar. (b) Photograph of the site of the first melting event at Tor Zawar (27 January 2010); courtesy of the Geological Survey of Pakistan, Quetta, (c) photograph of the excavations at the site of the first melting event, which occurred near the base of a steel pylon (to the left of the person) carrying a high-voltage electric supply line, and its support wire (in the foreground), (d) close-up view of the excavated site of the first melting event near the base of a steel support wire for the nearby steel pylon.

Figure 3. (a) View of the site of the second melting event showing the steel pylon and its support wire; black fragments of glassy material produced during the event may be seen near the base of these structures, (b) close-up view of the products of the second event near the base of the relevant steel pylon (seen in background), (c) another close-up view of basaltic products of the second melting event, scattered around the base of the steel support wire, (d) close-up view of collected samples of basaltic glass associated with the second melting event.

Survey Corporation 1961; Shah 1977; Bender & Raza 1995; Kassi et al. 2009). The Late Cretaceous Bibai Formation comprises thick succession of pillow lavas, volcanic ash, tuff, volcanogenic conglomerate, and breccias (Figures 1 and 2a), mostly of basaltic composition (Kazmi 1979; Siddiqui et al. 1996; Khan et al. 2000; Mahoney et al. 2002; Kassi et al. 2009). The belt occurred as result of collision of the Eurasian and Indian plates; therefore, it is tectonically and seismically active (Ambraseys & Bilham 2003). However, there is no evidence of any volcanic activity after the eruptions of the Late Cretaceous Bibai Formation (~74 Ma). Depth to the Moho in this area varies from 40 to 55 km (Jadoon & Khurshid 1996) and, therefore, total thickness of the lithosphere is likely to be considerably greater than this.

The third incident occurred at the Jang Tor Ghar massif of the well-known Muslim Bagh Ophiolites, 7 km SE of the town of Muslim Bagh (Figures 1 and 4). The surrounding area comprises outcrops of mafic and ultra-mafic rocks of the Jang Tor massif of the Muslim Bagh Ophiolites, which are part of the Bela-Waziristan Ophiolite Belt. It marks the western margin of the Indian plate with the Afghan block of the Eurasian plate (Hunting Survey Corporation 1961; Rossman et al. 1971; Khan et al. 2007); and is thought to be a relic of the Neo-Tethyan ocean floor obducted onto the Indian plate subsequent to closure of the Neo-Tethys and collision of the Indian plate with the Eurasian plate at the Cretaceous–Tertiary boundary or later in the Palaeocene–Early Eocene times (Allemann 1979; Sarwar 1992; Ahmed 1996; Gnos et al. 1996).

4. Field relations

All 3 incidents occurred near the bases of 3 different steel pylons, and their support wires, of the overhead electric transmission lines (Figures 2–4). At Tor Zawar Mountain, Ziarat District, the steel pylons are installed directly over a thick succession of the volcanogenic conglomerate of the Late Cretaceous Bibai Formation (Kazmi 1979; Khan et al. 2000; Kassi et al. 2009), which is composed of over 95% of basaltic boulders. In the Jang Tor Ghar, however, the affected steel pylon of the electric transmission line is installed over the alluvium, comprising mostly ultramafic fragments of the Muslim Bagh Ophiolites.

Figure 4. (a) View of the third melting event of 12 February 2011 near the base of another steel pylon of the electric transmission line at Jang Tor Ghar, Muslim Bagh, (b) close-up view near the base of steel pylon of the electric transmission line, (c) close-up view of collected samples of basaltic glass associated with the third melting event.

The occurrences are all very small [(first event; area: 8.2 × 1.9 m; thickness: ~15 cm), (second event; area: 1.5 × 1 m; thickness: ~10 cm), and (third event; area: 1.5 × 2 m; thickness: ~20 cm)], and only the first event displayed flow structures of the molten material, which has been extruded in a small concentric "boil" at the surface (Figure 2b). The glass samples of all the events have similar characters (Figures 2b, 3d, and 4b). The second event (of January 2011), reported in this paper by us, occurred ~300 m north of the first event (Figure 3).

In all these cases the high-tension overhead electric transmission line had not been ruptured and there is no report of repair of the transmission cables. However, the supporting wires of steel pylons had been melted near the surface of the ground, due to the heat of the fulgurites. Excavations (down to 2 m below the surface) of the first incident, as reported by Rana and Akhtar (2010), revealed that the vent consisted of a cylindrical pipe ~5 cm wide down to ~1 m, where a cone-like chamber (~60 cm × 45 cm) had developed; however, it did not extend further downward (Figures 2c and d). Most of the fulgurite material had been displaced or removed by excavation and souvenir hunting (Rana and Akthar 2010) and it was not possible to reconstruct the original relation of the various fulgurite lithologies.

The area is tectonically active and numerous small to medium-scale earthquakes are reported (National Seismic Monitoring Centre, Karachi, Pakistan, for 2010 and 2011 (Table 2). On the date of the first melting event a small quake was reported; however, the other 2 events were not associated with earthquakes. Meteorological information (Table 3) shows that all 3 incidents were closely associated with rainy weather.

5. Petrography and geochemistry

Samples of all 3 incidents are moderately to highly vesicular nonglassy as well as glassy (Figures 2e, 3d 4b). Kerr et al. (2010a) analysed samples of the first melting event and reported that vesicles make up 30–80 vol. % of the rock. They identified 2 petrographically distinct basalt types in the vesicular eruptive products. One of the basalt types consists of completely fresh, light brown glass with a few (<1 vol. %) partially resorbed quartz-rich xenoliths, ~500 µm in diameter (Kerr et al. 2010a, Figure 3). The other type is nonglassy and completely devitrified. It is virtually opaque in thin section and seem to be completely devitrified and has been altered extensively with the only recognisable minerals being clusters of radiating clinopyroxene needles (~100 µm in diameter) and small (10-20 µm) cubic opaque minerals (Kerr et al. 2010a, Figure 3). Samples are 'basaltic' on the basis of their MgO contents (4.1–7.2 wt. %); however, their trace-element geochemistry is consistent with an alkali affinity (Kerr et al. 2010a). Composition of the samples is comparable with that of both the Cretaceous alkali dolerite sills in the region and volcanic rocks of the Bibai Formation. Furthermore, all but 2 samples of the Bibai Formation fall within the MgO range of the analysed samples of the fulgurite, yet the Cretaceous rocks have consistently smaller incompatible trace element contents. Kerr et al. (2010a) suggest that the analysed samples have slightly different geochemical signatures that can be partially explained by crustal assimilation and derived mainly from a source in the garnet–spinel transition zone, i.e. well within the lithosphere. They further proposed that localised asthenospheric melting resulted in relatively depleted melts, which were substantially contaminated by fusible lithospheric mantle en route to the surface.

Table 2. Earthquakes data of Ziarat, Muslimbagh, and surrounding areas during 2010 and 2011 (Source: National Seismic Monitoring Centre, Karachi, Pakistan).

S. no.	Date	Origin time H-time (H:M:S)	Focaldepth (km)	Epicentre	Magnitude	**Location**
1.	2 Jan. 2010	23:48:08 PST	10	68 km NE of Quetta, Pakistan	2.7	30.18 N 67.71 E
2.	8 Jan. 2010	17:58:48 PST	10	81 km SE of Quetta, Pakistan	2.4	29.61 N 67.69 E
3.	27 Jan. 2010	20:56:00 PST	60	Near Quetta Pakistan	3.9	28.41 N 66.84 E
4.	1 Feb. 2010	21:22:09 PST	10	Near Ziarat Quetta	3.2	29.24 N 68.05 E
5.	4 Mar. 2010	21:06:44 PST	10	Near Ziarat, Pakistan	3.7	30.36 N 67.34 E
6.	5 Mar. 2010	18:15:23 PST	10	Near Ziarat, Pakistan	2.2	30.20 N 67.50 E
7.	28 Mar. 2010	23:21:07 PST	10	Near Ziarat, Pakistan	2.8	30.06 N 68.46 E
8.	17 April 2010	20:45:35 PST	10	Near Ziarat, Pakistan	3.5	30.50N 67.70E
9.	12 May 2010	09:55:59 PST	58	Near 29 km SE of Sibi, Pakistan	3.8	29.41 N 68.14 E
10.	3 May 2011	01:17:01 PST	10	36 km NW of Loralai, Pakistan	3.6	30.66 N 68.44 E

Megascopically, samples of all 3 events have similar characters; however, it is envisaged that samples of the second event of Tor Zawar, Ziarat, will have geochemical characters similar to those of the first event, because host rock of both incidents is the volcanogenic conglomerate of the Late Cretaceous Bibai Formation, involving its partial melting. However, samples of the third event, of the Jang Tor Ghar massif, Muslim Bagh, may have geochemical signatures comparable to those of the ophiolites.

6. Discussion

The basaltic melt at Tor Ziwar, Ziarat District, has earlier been interpreted as the result of volcanic activity (Rana & Akhtar 2010; Kerr et al. 2010a). In view of the very small sizes of the occurrences we think that use of the terms of "eruption" and "magma" by Rana and Akhtar (2010) and Kerr et al. (2010a) for the first occurrence on 27 January 2010 is inappropriate. Further, excavations by Rana and Akhtar (2010) demonstrate that the occurrence was entirely superficial and did not extend deeper than 1.5 m. They also state that the first event coincided with a M3.9 tremor (focal depth: 60 km) at 20:56:00 local time (epicentre: 28°24.6N; 66°50.4E), implying their relevance. No doubt the area is seismically active and earthquakes of up to M6 are relatively common (Ambraseys & Bilham 2003); however, in view of the earthquakes record of the National Seismic Monitoring Centre, Karachi, Pakistan, for 2010 and 2011 (Table 2), we think that the 3 fulgurite occurrences have no relevance with the earthquakes. The concurrence of the first fulgurite event with the M3.9 tremor is merely a coincidence. The second event of the Tor Zawar, Ziarat District, and the third event of the Jang Tor Ghar, Muslim Bagh, occurred during the months of January and February 2011, respectively; during this period no earthquakes occurred in these areas and surroundings.

Kerr et al. (2010a) ruled out the possibility of re-melting of local basaltic rocks by short circuiting of a ruptured high-tension electrical cable, although acknowledging the possibility that rupturing of electrical cables may result in a massive release of electrical energy and melting of the rocks. Similar occurrences close to steel pylons have been reported from India and Austria (e.g. Manimaran et al. 2001; Bhattacharyya et al. 2002; Brandstätter et al. 2009). However, there are significant differences between these occurrences and those at the Tor Zawar, Ziarat, and Jan Tor Ghar, Muslim Bagh, Pakistan. They are clearly the result of surface melting (including melting of soil) in shallow pits with little in the way of reported vents, and in the Austrian example remnants of the electric cable had been welded into the glass. Kerr et al. (2010a) argue that there was little or no surface melting at Tor Zawar, other than that caused by the erupted molten rock flowing on the surface. They further argue that magmatism in this region is unusual and quite unexpected; however, they present mantle-melt modelling, whereby a significant amount of melting that contributed to this magmatic incident probably occurred within the lithospheric mantle.

In the Ziarat, Muslim Bagh and surrounding regions most of the precipitation is received during the months from December through March (Buller 1969). The first fulgurite event of 27 January 2010 clearly coincides with rainy weather in Ziarat District (Table 3). The exact date of the second event (January 2011) is not known, but precipitation of up to 10.6 mm occurred during January

Table 3. Daily precipitation (mm) during 2010 and 2011 in the Ziarat (30°23′N, 67°42′E); data source: Department of Irrigation, Government of Balochistan, Quetta, Pakistan.

	2010				2011			
Date	JAN	FEB	MAR	APR	JAN	FEB	MAR	APR
1	-	-	-	-	-	-	24.80	-
2	-	-	-	-	-	-	27.20	-
3	1.10	-	14.90	-	-	2.40	0.50	-
4	-	-	2.80	-	-	0.60	0.60	-
5	-	-	-	-	-	7.30	6.00	-
6	-	0.50	19.20	-	-	-	0.90	-
7	-	8.40	-	-	-	6.60	6.40	-
8	-	26.10	-	-	-	-	-	6.30
9	-	2.70	-	-	-	-	-	-
10	-	-	-	-	-	0.70	-	-
11	-	-	-	1.10	-	10.60	-	25.70
12	-	-	-	-	-	22.30	-	12.20
13	0.50	-	-	-	-	32.40	-	-
14	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-
16	-	-	-	-	-	0.50	-	-
17	-	-	-	-	-	-	-	-
18	-	-	-	-	-	9.00	-	-
19	-	-	-	-	-	2.20	-	-
20	-	-	-	-	1.60	3.20	-	-
21	-	-	-	1.70	0.50	-	-	-
22	-	-	-	-	-	-	-	-
23	-	-	-	-	-	9.70	-	-
24	8.10	-	-	-	-	-	-	-
25	-	-	-	-	-	1.90	-	-
26	-	-	-	-	-	-	-	-
27	0.20	-	-	4.30	-	-	-	-
28	1.50	-	-	6.10	-	6.40	-	-
29	14.20	-	-	-	4.70	-	-	-
30	-	-	-	1.10	3.80	-	-	-
31	-	-	-	-	-	-	-	
Total	25.60	37.70	36.90	14.30	10.60	115.80	66.40	44.20

2011. The third event of the Jang Tor Ghar, Muslim Bagh, occurred on 12 February 2011, which again clearly coincides with high precipitation (Table 3). Therefore, we conclude that the events of the Tor Zawar, Ziarat District and Jang Tor Ghar, Muslim Bagh, show relevance with the cloudy weather, precipitation, and lightning.

The 2 fulgurite events of the Tor Zawar, Ziarat District, as well as the third event at Jang Tor Ghar, Muslim Bagh, have striking similarities by occurring near the bases of 3 separate pylons, and their support wires, of the overhead electric transmission line (Figures 2 and 3), which could not be a coincidence. We are convinced that these were incidents of accidental fulgurites, which occurred through the steel pylons of the electric supply line. Their ionising effect added in attracting the lightning to the sites. The atmospheric lightning struck the outcrops through the pylons, and support wires, of the electric supply line. The steel pylons, and their supporting wires, performed as means to transmit atmospheric lightning directly to the outcrops (Figures 2–4). Incidents of lightning striking on steel pylons of overhead electric transmission lines, towers, trees etc. are very common; however, in these cases they involve transmission of high amounts of energy through the steel pylons to partially melt outcrops of mafic and ultramafic rocks. The transmission of lightning through steel pylons of electric supply lines has also been reported from Portugal by Martin-Crespo et al. (2009). In this case the electric wire had been broken by the incident, but still the fulgurite formed from the base of the pylon downwards in contrast to the pseudofulgurite reported by Brandstätter et al. (2009), which was caused by surficial melting where the broken electric wire had fallen to the ground.

The petrography and geochemistry of samples of the first incident of the Tor Zawar, Ziarat, shows close similarity to the volcanic rocks and fragments of the volcanogenic conglomerate of the Bibai Formation (Kerr et al. 2010a), which have been interpreted as hot-spot related volcanics (Khan et al. 2000; Siddiqui et al. 1996). However, in the existing compressional geotectonic regime of the Sulaiman Fold-Thrust Belt, and very thick lithosphere, it is unlikely that they were eruption incidents of asthenospheric magma, as proposed by Kerr et al. (2010a).

Kerr et al. (2010a) further argue that the area lies between the surface expression of 2 major, and still active, thrust faults (the Bibai and Gogai faults), which formed during collision of the Indian and Eurasian plates and are likely to extend to considerable depths. They conclude that the magmas were generated in the asthenosphere, and were substantially modified by interaction with enriched lithosphere, and although the Bibai and Gogai thrusts are compressional features they could have provided a route for the magmas to migrate to the surface. We disagree with the notion of Kerr et al. (2010a) that the Gogai and Bibai thrusts are likely to extend below 45–55 km depths in order to provide routes for magma that was generated in the asthenosphere to migrate to the surface. The overall tectonics of the region has been interpreted as thin-skinned and in the Sulaiman Fold-Thrust Belt Triassic through Pliocene successions overlie the crystalline basement of the Indian plate (Jadoon & Khurshid 1996).

Kerr et al. (2010a) indicate that the chemistry of the Bibai Volcanics (Kerr et al. 2010b) and the analysed samples are broadly similar; however, the Bibai Volcanics have lower concentrations of incompatible trace elements at equivalent MgO contents. They suggest that elevated SiO_2 content in one of the analysed samples, combined with the presence of partially melted quartz-rich xenoliths, suggests that this sample has been contaminated by siliceous country rocks. Analysis of the glass reveals that the xenocrysts have increased the bulk SiO_2 content of the whole rock and slightly diluted the other major and trace elements. Using the composition of the glass and assuming an uncontaminated SiO_2 content of ~50 wt. %, the incorporation of 5–8 vol. % of quartz-rich sediment could explain the elevated silica content of the sample. The higher levels of Rb, Th, and K_2O in one of the samples are also suggestive of crustal contamination. Kerr et al. (2010a) also suggest that the mantle source was relatively depleted, as the modelling curve that best fits the data is that of a depleted mantle composition.

The broadly similar chemistry of the analysed samples of the first incident by Kerr et al. (2010a) to those of the Bibai Volcanics supports our notion, because melting of the volcanogenic conglomerate of basaltic composition will produce volcanic glass of similar composition. The elevated SiO_2 content in one of the analysed samples, combined with the presence of partially melted quartz-rich xenoliths, is not because the "magma" had been contaminated by siliceous country rocks, as suggested by Kerr et al. (2010a). Instead, the near-surface melting of the volcanogenic conglomerate of the Bibai Formation, containing minor proportions of other varieties of rock fragments, may have caused elevated SiO_2 content of the analysed samples. The higher levels of Rb, Th, and K_2O, which were attributed to crustal contamination, may also be due to the mixed boulder types of the volcanogenic conglomerate. Further, the composition of fulgurites may be modified to varying degree by vaporisation (Pasek et al. 2012). Therefore, we disagree with the interpretation of Kerr et al. (2010a) that the Tor Zawar events were "magmatic eruptions of basaltic magma" derived from mantle; instead they were surface melting events related with incidents of lightning, which produced fulgurite. In these incidents the steel pylons, and their support wires, performed as means to transmit atmospheric lightning directly at the outcrops of volcanogenic conglomerate of the Bibai Formation. There is no reported rupture of the high-tension electrical cable related to the incidents, and melting caused by short circuiting of a ruptured cable as described by e.g. Manimaran et al. (2001), Bhattacharyya et al. (2002), and Brandstätter et al. (2009) can be ruled out. The 3 incidents of similar nature, during the winter rainy seasons of 2010 and 2011 of the area, are undoubtedly incidents of surface melting and fulgurite strikes.

We here report 3 occurrences of rock-fulgurites at Tor Zawar, Ziarat District, and Jang Tor Ghar, Muslim Bagh, Pakistan; the first 2 occurred on 27 January 2010 and sometime during the month of January 2011 at Tor Zawar, Ziarat District. The third occurred at Jang Tor Ghar, Muslim Bagh, on 12 February 2011. All 3 were incidents of near-surface melting that occurred near the bases of steel pylons, and their support wires, of the overhead electric transmission line, which performed as means to transmit atmospheric lightning directly to the outcrops, transmitting enough energy to partially melt the outcrops of mafic and ultramafic composition. We disagree with the notion of Kerr et al. (2010a) that the first incident of the Tor Zawar, Ziarat District, was an eruption event of basaltic magma, derived from mantle; instead, all these events were occurrences of rock-fulgurites, associated with steel pylons of the overhead electric transmission line. The studied rock-fulgurites result from relatively large volumes of molten rock, which was sufficient to form very small-scale extrusive flow to the surface.

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