The Kamikatsura event in the Gold Hill loess, Alaska

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[1] As part of a broader geological study of loess/palaesol sequences in Alaska, the paleomagnetism of a section at Gold Hill near Fairbanks has been investigated. Samples were collected at 5 cm intervals through a 5 m loess-paleosol-loess sequence. Detailed alternating field demagnetization of the natural remanent magnetization yields excellent results (average MAD = 2°). The Brunhes-Matuyama (B-M) polarity transition is present at the level of the paleosol, which was formed during Oxygen Isotope Stage 19. A systematic perturbation in both declination and inclination occurs ~1.0–1.5 m below the B-M boundary. The corresponding virtual geomagnetic poles define a track centred on the 60°W meridian from high southerly to equatorial latitudes and back again. This is in very good agreement with results from a sequence of lava flows on the island of Maui that are regarded as a record of the Kamikatsura event. The Alaskan results thus confirm the reality of this geomagnetic feature, and simultaneously provide a firm chronological control point for ongoing geological investigations. Mineral magnetic experiments indicate that the remanence of the Gold Hill loess is dominated by magnetite and/or maghemite, with no subsequent chemical overprinting by hematite and/or goethite. **Citation:** Evans, M. E., B. J. L. Jensen, V. A. Kravchinsky, and D. G. Froese (2011), The Kamikatsura event in the Gold Hill loess, Alaska, *Geophys. Res. Lett.*, *38*, L13302, doi:10.1029/2011GL047793.

1. Introduction

[2] The major pattern of chrons that define the geomagnetic polarity time scale (GPTS) is now well established and provides a robust chronological framework that widely applied in the earth sciences. But much uncertainty surrounds the finer-scale features (variously known as events, excursions, cryptochrons, microchrons, aborted reversals), whose interpretation remains in a state of flux. Their brevity makes them difficult to find, and even harder to establish reliable substructure. Are they truly global geomagnetic phenomena? Do they reflect complex recording processes? Or inadequate laboratory procedures? Nevertheless, a large number of candidates have been proposed and are summarized in a comprehensive review by *Laj and Channell* [2007]. Here, we report new data relevant to this debate from loess deposits in Alaska.

[3] Charles Lyell, in the 1840's, was the first to describe important loess deposits in North America, but Alaskan loess was not investigated thoroughly until a century later [*Péwé*, 1955]. Early magnetic studies of loess in North America were reported by *Jones and Beavers* [1964] and by *Packer* [1979] in the states of Illinois and Washington, respectively. Similar work in Alaska was initiated by *Begét and Hawkins* [1989], *Begét et al.* [1990], and *Westgate et al.* [1990]. Here we focus on a declination/inclination perturbation that we argue is a record of the 'Kamikatsura excursion'. This is an elusive feature that falls in the time interval between the Jaramillo Subchron and the Matuyama/Brunhes transition, an interval for which there is "clearly much to be done to resolve the behaviour of the geomagnetic field" [*Laj and Channell*, 2007, p. 398].

2. Methods and Results

[4] The section studied is located at Gold Hill (64.9°N, 147.9°W), some 10 km west of Fairbanks, Alaska (Figure 1). Gold Hill extends for several kilometres along the George Parks Highway, and the area investigated is located within the University of Alaska, Fairbanks, Troy Péwé Climatic Change Permafrost Reserve. Previous studies have examined four trenches, known as Gold Hill I, II, III and IV [e.g., *Westgate et al.*, 1990; *Preece et al.*, 1999]. The trench utilized for this work is Gold Hill IV (Figure 1).

[5] Samples were collected by pushing 2.5 cm-diameter plastic cylinders horizontally into the cleaned face of the section at 5 cm stratigraphic intervals. They were oriented by means of a Brunton compass, allowing for the local declination. A total of 100 samples spanning 5 metres of section were collected. All remanence measurements were made on a horizontal 2G Enterprises DC-squid cryogenic magnetometer equipped with an alternating-field (AF) demagnetizer. The progressive demagnetization scheme involved 24 steps up to a maximum field of 100 mT, the results being interpreted with the aid of orthogonal vector component plots and principal component analyses. Magnetic mineralogy was assessed by means of isothermal remanent magnetization (IRM) and magnetic hysteresis measurements. Progressive IRMs were given in a 2G Enterprises Model 670 IRM Pulse Magnetizer using 36 steps up to a maximum of 0.60 T. Hysteresis loops were determined on a variable force translation balance (VFTB), with a total of 76 steps between ±0.95 T.

2.1. Magnetic Mineralogy

[6] Examples of hysteresis loops and isothermal remanent magnetization (IRM) acquisition curves are given in Figure 2. For the former the paramagnetic contribution was removed by subtracting the linear high-field slope; both samples exhibited very good linearity (R > 0.999) above 0.5 T. The results are typical of low-coercivity minerals such as magnetite and/or titanomagnetite, and give no evidence of magnetically hard minerals such as hematite and goethite. Coercive force (H_c), saturation magnetization (M_s), and sat-

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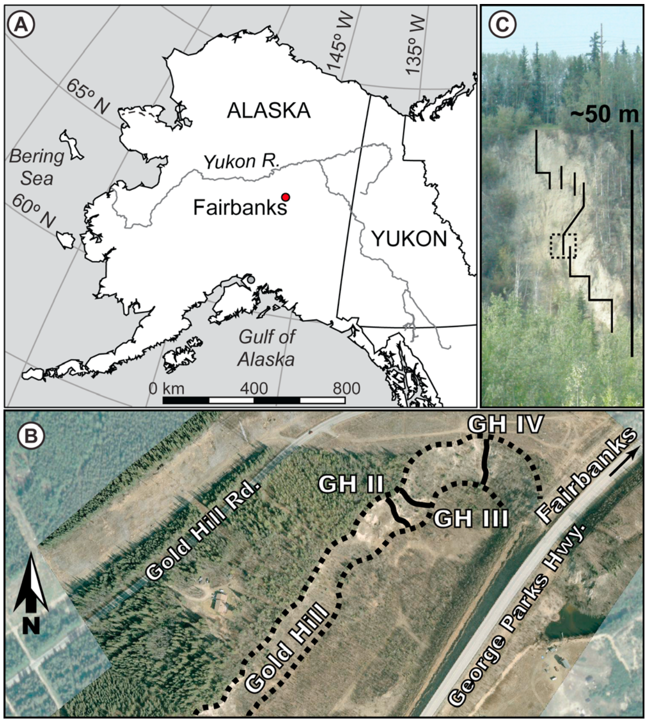

Figure 1. (a) Fairbanks is in the interior of Alaska, where thick accumulations of loess, formed beyond the limits of glaciation, are relatively common. (b) Satellite image of Gold Hill (GH) (http://www.alaskamapped.org). (c) GH IV as seen from the George Parks Hwy, the 5 m section discussed is highlighted by the dashed box.

uration remanence/saturation magnetization (M_{rs}/M_s) ratios are 13 and 16 mT, 0.072 and 0.134 Am^2/kg, and 0.14 and 0.15 for samples GH387 and GH479, respectively. IRM median acquisition fields (MAFs) are 72 and 59 mT for samples GH389 and GH408, respectively. Comparison of these values with published compilations for natural and synthetic Fe_3O_4 powders [*Dankers*, 1981; *Dunlop and Özdemir*, 1997] indicates that the Gold Hill loess contains a mass fraction of $\sim 1 \times 10^{-3}$ of magnetite grains with dimensions of a few microns or less. These findings closely parallel those reported from a similar boreal loess site at Kurtak in Siberia [*Chlachula et al.*, 1998].

2.2. Natural Remanent Magnetization

[7] For principal component analysis we imposed a minimum of 5 AF steps to define a characteristic direction. From a total of 100 samples, 91 could be readily interpreted. The average number of AF steps used to define the characteristic directions was 14, the average MAD value was 2°, and the largest value was 10°. The remaining nine samples were strongly overprinted and the underlying primary remanence isolated was generally weak. For six of them, characteristic directions were determined by the traditional end-point method. The number of AF steps used to define the end-points ranged from 5 to 12, and the angular standard deviations ranged from 3 to 8° with an average of 6°. No

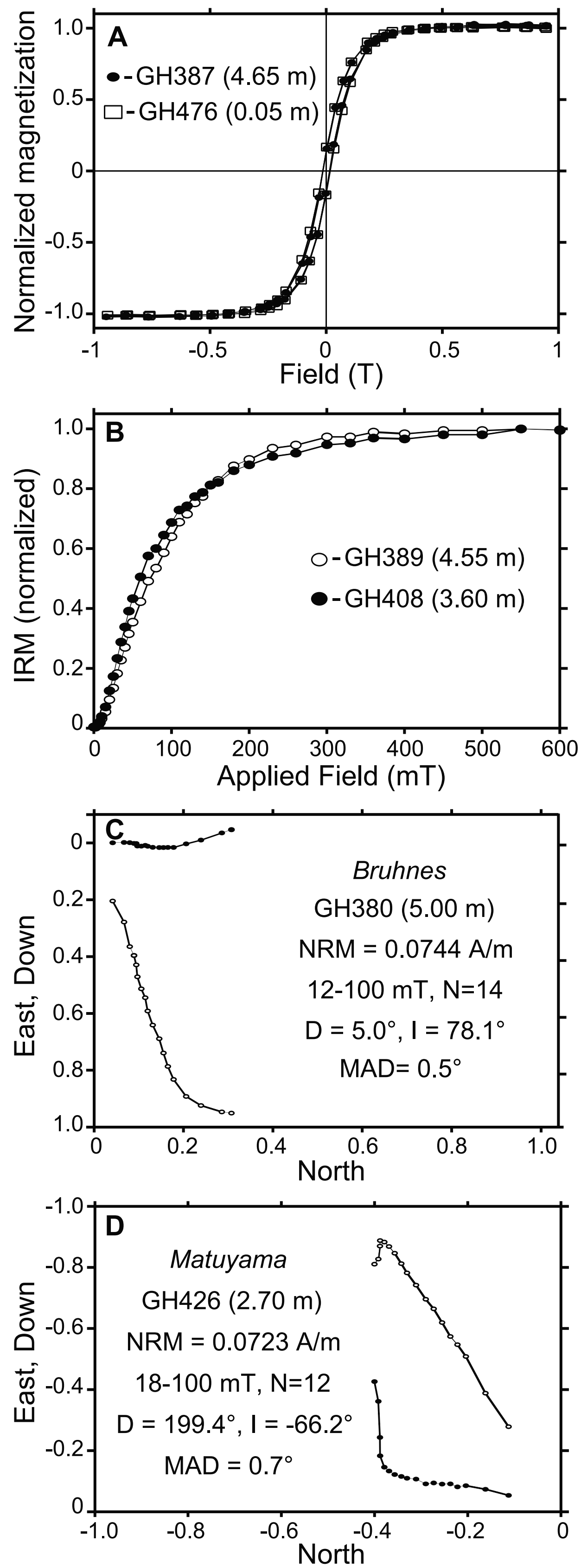

Figure 2. (a) Normalized hysteresis loops after paramagnetic correction. (b) Normalized isothermal remanent magnetization acquisition curves. (c, d) Alternating field (AF) demagnetization orthogonal vector component plots. Solid (open) symbols are in the horizontal (vertical) plane. Axes are normalized.

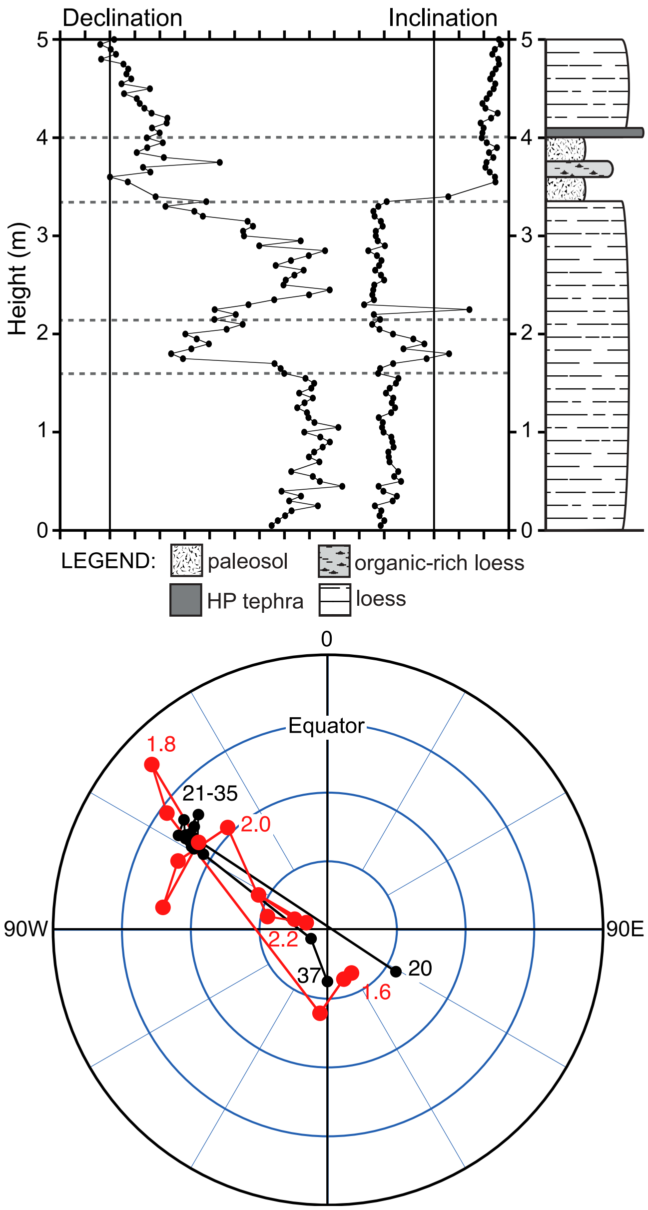

Figure 3. (top) Declination and inclination versus height and stratigraphy. Dashed lines indicate approximate limits of the MIS 19 paleosol and Kamikatsura event. (bottom) Kamikatsura VGP paths recorded between 1.60 and 2.20 m at Gold Hill (red), and by flows 20 to 37 on Maui (black). This polar projection represents a map of the world centred on the South Pole and extending out beyond the equator to the perimeter at latitude 30°N. For clarity, continental outlines are omitted.

reliable characteristic directions could be isolated from the samples at stratigraphic heights of 0.65, 3.45, and 3.50 m.

[8] Two examples (one normal, one reversed) of the characteristic directions identified by principal component analysis are illustrated in Figure 2. Robust results like these are typical of much of the collection and testify to the excellent paleomagnetic recording properties of the Gold Hill Loess. The directional results for 5 m section are illustrated in Figure 3 as declination and inclination profiles. These data are listed in Table S1 of the auxiliary material, along with the corresponding virtual geomagnetic pole positions (VGPs).[1]

3. Discussion

3.1. Brunhes-Matuyama Boundary

[9] Our sampling strategy was guided by previously published lithostratigraphic, tephrochronological, and paleomagnetic investigations [*Westgate et al.*, 1990; *Preece et al.*, 1999], which made it relatively easy to target the Brunhes-Matuyama (B-M) boundary. A paleosol is present at the boundary, and a tephra bed, known as the HP tephra (601 ± 50 ka), is reworked into the top of the palaesol (Figure 3 and Table S2). The inclination rapidly switches sign over a stratigraphic distance of 20 cm (between 3.35 and 3.55 m), with only one transitional direction present. It is noteworthy that two of the three samples from which primary signals could not be isolated fall in this interval. This is probably due to the fact that they contain both polarities, an original reversed component and a strong normal overprint. Such compound magnetizations have been widely reported from the Chinese Loess Plateau [e.g., *Rutter et al.*, 1991]. Unlike the Chinese deposits however, the Gold Hill Loess does not appear to suffer from the problem of extended lock-in of the paleomagnetic signal [*Evans and Heller*, 2001].

[10] The transitional nature of the B-M boundary through base of the palaesol, which indicates that the palaesol is conformable with the loess below, and the minimum age provided by HP tephra, suggests that the paleosol likely represents Marine Isotope Stage (MIS) 19. Having the B-M boundary present within MIS 19 is consistent with marine records [*Tauxe et al.*, 1996]. In China, on the other hand, it is usually found in glacial loess L8 implying a lock-in delay of as much as 25,000 years [*Spassov et al.*, 2003]. The declination profile within the Brunhes exhibits more variability than the corresponding inclination pattern, and only slowly returns to northerly directions over the uppermost metre or so. These details are, for the moment, rather secondary since the reason for seeking the B-M boundary was simply to provide chronological control. The main purpose of this paper is to report a paleomagnetic feature found below the B-M boundary that we regard as a record of the Kamikatsura event, to which we now turn.

3.2. Kamikatsura Event

[11] A systematic swing in declination and inclination is seen between 1.60 and 2.20 m, but it more instructive to consider the corresponding VGP's (Figure 3). They define a swing from high southerly latitudes through South America to equatorial latitudes, and back again. This agrees extremely well with the results of *Coe et al.* [2004] for the Kamikatsura event recorded in a sequence of lava flows on the island of Maui. This new record confirms the reality of the Kamikatsura event, and because this event is well dated at 900.3 ± 4.7 ka [*Coe et al.*, 2004], it provides valuable chronological control for ongoing efforts to unravel the rich Quaternary paleoenvironmental records of Alaska.

[12] The stratigraphic separation between the B-M boundary and the Kamikatsura event implies a sedimentation rate on the order of 1cm/kyr, and thus indicates that the pertur-

[1] Auxiliary materials are available in the HTML. doi:10.1029/2011GL047793.

bation itself lasted at least 25,000 years. This is considerably longer than the features listed as geomagnetic excursions by *Laj and Channell* [2007, see Tables 2 and 3], although they give no estimate for the duration of the Kamikatsura itself. As their discussion makes clear, this is because of the considerable uncertainty associated with much of the relevant data. Additionally, the length of the event provided by the calculated sedimentation rate should be considered a maximum estimate. Loess accumulation rates in Alaska have been highly variable through time [e.g., *Muhs et al.*, 2003, 2008], and unconformities can be present, but not clearly discernable. Nevertheless, the ~1cm/kyr suggested above is supported by the magnetostratigraphy of Gold Hill III [*Preece et al.*, 1999], which implies rates of ~1.5 cm/kyr between the Cobb Mountain subchron and the base of the Jaramillo subchron, and ~2.7 cm/kyr between the top of the Jaramillo and the B-M boundary.

[13] *Laj and Channell* [2007] raise the possibility that it is a double event. This could then involve the inclination spike at height 2.25 m in the Gold Hill section (Figure 3). We are reluctant to give much weight to a single sample, but it is interesting to note that *Preece et al.* [1999] also find a double feature about 1 metre below the B-M boundary in their paleomagnetic profile.

[14] Despite the current lack of a firm estimate for the duration of the Kamikatsura excursion, the corresponding cluster of VGPs (Figure 3) offers a useful window onto the behaviour of the geomagnetic field. Clusters of this kind have been attributed to persistent near-radial flux concentrations coming out of the Earth's core which are themselves closely tied to seismic anomalies in the lower mantle [*Hoffman*, 1992]. *Hoffman and Singer* [2008] go on to argue that the flux concentrations themselves are generated by a shallow core (SCOR) field that is essentially independent of the deeper source responsible for the bulk of the geocentric axial dipole (GAD) field, and that this "dichotomy may be the key to solving the problem of the reversing dynamo".

4. Conclusion

[15] A 5 m section of Gold Hill loess near Fairbanks, Alaska yields evidence of the Brunhes-Matuyama transition. The coincidence of this boundary with Isotope Stage 19 indicates that the Gold Hill loess carries a post-depositional remanence that does not suffer from the long lock-in delays common in the Chinese Loess Plateau. This is supported by mineral magnetic experiments showing that magnetite and/or maghemite are the dominant magnetic minerals present, with no evidence for later chemical overprinting by hematite and/or goethite.

[16] A metre or so below the B-M boundary a systematic directional swing is found which yields VGPs in very close agreement with the Kamikatsura event observed in a sequence of lava flows on the island of Maui. This provides additional chronological control for the ongoing effort to unravel the geological history of Alaska. It also confirms the Kamikatsura event as a real geomagnetic phenomenon, which may have lasted more than 25,000 years. The combined Alaska/Hawaii VGP cluster in South America provides another example of a stationary flux concentration, and thus strengthens the SCOR/GAD composite model of the geomagnetic field.

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