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Climate of the Past
Discussions

Interactive comment on "Magnetostratigraphy of sediments from Lake El'gygytgyn ICDP Site 5011-1: paleomagnetic age constraints for the longest paleoclimate record from the continental Arctic" *by* E. M. Haltia and N. R. Nowaczyk

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REPLY TO REFEREES' COMMENTS REGARDING:

Magnetostratigraphy of sediments from Lake El'gygytgyn ICDP Site 5011-1: paleomagnetic age constraints for the longest paleoclimate record from the continental Arctic" by E. Haltia and N. Nowaczyk. Submitted to Climate of the Past for publication in the special issue "Initial results from lake El'gygytgyn, western Beringia: first time-continuous Pliocene-Pleistocene terrestrial record from the Arctic"

The primary objective of the proposed paper is to present an overview of the magnetostratigraphic data obtained from three long cores from El'gygytgyn from ICDP Site 5011-1 and to interpretate these data in order to set chronological tie-points for the long sediment record. A secondary aim of the paper is to provide the reader with basic information regarding mineral magnetic characteristics measured from sediments enclosed in core catchers, creek sediments and rock samples collected from the catchment (colluvium and bedrock). Mineral magnetic results are presented in the same paper together with magnetostratigraphy in order to provide the reader a wider, but hardly not exhaustive, understanding of the origin and characteristics of magnetic minerals in Lake El'gygytgyn. The aim of the paper, however, is not to provide a detailed analysis of sedimentary mineral magnetic characteristics and processes affecting them. This is because of 1) Sediments enclosed in u-channels were considered archival material and not available for the purposes of this study, 2) The aim of our working group was to reconstruct a geochronology for the sediments of El'gygytgyn from ICDP Site 5011-1, but not to conduct detailed mineral magnetic analyses, which was granted for other working groups. So far, mineral magnetic characteristics of sediments from Lake El'gygytgyn have been investigated by Nowaczyk et al. (2002), Murdock et al. (2012) and Minuyk et al. (2012).

AUTHOR REPLY TO INTERACTIVE COMMENTS PRESENTED BY AN ANONYMOUS REFEREE

The greatest concern expressed by the anonymous Referee appears to be the mineral magnetic variability due to magnetite dissolution in the sediments of Lake El'gygytgyn as reported by Nowaczyk et al. (2002) and Murdock et al. (2012) and its implications to the fidelity of the geomagnetic reversal stratigraphy reconstructed from the sediments. We admit this is a very important point, because major reversals reconstructed from the sediments form the main chronological frame. They are used as chronological tie-points for further refining the chronology of the sediment composite by means of tuning different proxy parameters with respect to marine oxygen isotope record (LR04) and

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Northern Hemisphere summer insolation. One of these proxy parameters is magnetic susceptibility (MS), which reflects concentration of magnetic minerals in the sediment. MS record from Lake El'gygytgyn is characterized by repeated and cyclic variations with a large amplitude. While part of this variability is undoubtedly due to decreased sediment and therefore magnetic mineral supply to the lake, part of the cyclic variations is explained by dissolution of magnetite in lake bottom. In their study of two pilot composite cores from Lake El'gygytgyn (PG1350 and PG1351), Nowaczyk et al. (2002) propose that the mechanism producing marked peaks and troughs in MS record, which range more than two orders of magnitude, is reductive dissolution of magnetic minerals during cold climate stages. According to the theory, production of organic matter continues to operate below ice cover, and lake bottom becomes anoxic as a result of decomposition of organic matter in conditions where availability of dissolved oxygen is restricted in the stratified water column under lake ice. Reductive lake bottom conditions, which prevail during cold climate stages, result in finer magnetite particles becoming selectively dissolved due to their smaller surface/volume ratio, which is then reflected as troughs in MS record. As a result, MS record from Lake El'gygytgyn provides a high-resolution astronomically forced climate record from the Arctic. The question is what is the effect of the lake bottom redox variations to magnetostratigraphic record? In their mineral magnetic study of pilot cores from Lake El'gygytgyn, Nowaczyk et al. (2002) state that haematite concentration dominates sediment magnetic assemblage in terms of mass-%, but magnetic properties are nevertheless dominated by magnetite even during cold climate stages, where S-ratios reach 0.8 (on a non-linear scale where 0 = pure haematite, 1 = pure magnetite). This would translate into a magnetite/haematite ratio of ca. 1:25. We speculate that part of ferrimagnetic grains and their directional information survive diagenetic reductive dissolution. It is possible that part of detrital ferrimagnetic minerals in Lake El'gygytgyn sediments are preserved in the crystal lattices of other, chemically more resistant minerals, and this remaining fraction carries information of primary magnetization acquired about the time of sediment deposition. It is not uncommon that sediments affected by selective magnetite dissolution can still

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preserve a primary magnetic directional record (Demory et al., Global and Planetary Change 46 (1-4) 2005), even though reconstructing relative paleointensity may clearly be compromised from such sediments.

The findings from a detailed mineral magnetic study using a short pilot sediment core LZ1029-7 from Lake El'gygytgyn by Murdock et al. (2012) support the conclusions by Nowaczyk et al. (2002) of dissolution of magnetite in the sediments from Lake El'gygytgyn. Using visual observations and/or magnetic measurements, Murdock et al. (2012) have detected iron-bearing (non-magnetic) minerals of secondary origin in the core LZ1029-7, including vivianite, and possibly also siderite and rhodochrosite. These minerals can precipitate in anoxic lake bottom conditions such as Lake El'gygytgyn where iron is available through reductive dissolution of ferrimagnetic minerals. Tentative results by Minyuk et al. (2012) suggest the presence of a metastable iron sulphide greigite in Lake El'gygytgyn sediments. Whether it would have formed approximately at the time of sediment deposition or sometimes after it, is an open question, and deserves to be studied in more detail in order to estimate the fidelity of the paleomagnetic record. Such investigation is, however, beyond the scope of the present paper. In addition, alternating field demagnetization, in general, did not show evidence for the acquisition of a gyro-remanent magnetisation, as it is typical for greigite (Ron et al., Geophys J Int 170 (1), 2007).

The main object of this study is not to discuss mineral magnetic variability with respect to the magnetostratigraphic record, which is mainly reconstructed from u-channel samples. There are two main causes for this. First of all, measurement and demagnetization of NRM from all the three long cores was a time consuming process. Secondly, after NRM and its demagnetization measurements were executed, sediments enclosed in U-channels were considered as a kind of sediment archive, and they were not available for further mineral magnetic analyses. Moreover, detailed mineral magnetic measurements from lake sediments are studied by other working groups. As a result, direct and side-by-side comparisons of mineral magnetic variability and magnetostratigraphy are not possible.

Despite the selective dissolution of magnetic minerals in the sediments of Lake El'gygytgyn, its sediments appear to carry a nice magnetostratigraphic record.

REPLY TO THE SPECIFIC COMMENTS PRESENTED BY AN ANONYMOUS REFEREE

Referee comment (RC): A little more information on the drilling method, was it all APC or was part of it XCB/RCB drilled as implied by the "discs"?

Author comment (AC): Hydraulic piston corer (HPC), extended nose corer (EXC) and alien bit corers (ALN) were employed. We use the word "disc" to describe the shape of sediment material drilled near the bottom of core 1C. "Discs" are flat, half-cylindric pieces of sediment, which are cemented and hard. We refer to Melles et al. (2011) for detailed description of the drilling.

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RC: Would be good to know more about the discrete measurements, assume they were single measurements after each demagnetization step using a pass through system?

AC: Measurement of NRM and its demagnetization from discrete samples was performed in the same manner as sediments enclosed in u-channels. NRM was measured with 2G Enterprises 755-SRM cryogenic long-core magnetometer. The NRM was progressively demagnetized in ten steps (5, 10, 15, 20, 30, 40, 50, 65, 80 and 100 mT) with the magnetometer's inline three-axis demagnetizer.

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RC: The MAD values should be presented somewhere and if the demagnetization steps used to calculate the component differ substantially, that should also be presented.

AC: Plots showing MAD values for the core 1A, 1B and 1C are included now.

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RC: Specifics Page 5083, line 15, discs are often termed biscuits and I assume that the drilling technique used here was different, though this was not discussed.

AC: We mention earlier the use of alien bit corer, which was used to drill the deepest part of sediment record. Although the term “biscuit” is new to us in this sense, we have added it to the text.

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RC: Page 5083, line 28, at which lab were the results obtained?

AC: All magnetic measurements were performed in Paleo- and Rock Magnetic Laboratory in Potsdam, Germany. This information has been added to the text.

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RC: Page 5084, line 7-8, so what was done if the MAD values were higher than 5? Were these the only ones used?

AC: ChRM data was not filtered in any way. All the available data is presented.

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RC: Page 5084, line 9, how was the depth of integration determined? Typically using the width of the response function at half height yields distances of 4.5 cm (e.g.,Weeks et al., 1993) to 7.7 cm (Jackson et al. 2010) depending on the coils and the system.

AC: The width over which the pick-up coils integrate information has been determined by N. Nowaczyk specifically for the system used in the Potsdam Paleo- and Rock Magnetic Laboratory. For that, a small piece of basalt (2 mm diameter) was moved throught system and the response of the sensors was recorded. Thus, distances of about 9.5 cm half height were obtained for the system used in Potsdam.

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RC: Page 5084, line 13, change “Unless otherwise is stated” to Unless otherwise stated

AC: Corrected

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RC: Page 5087, line 5, its important to point out that there is significant variability on the meter to 10s of meter scale and that prior work has been done assessing the cause of this variability. This is ignored in this part of the manuscript and it should not be.

AC: In our opinion it would be confusing to get back to this issue at this point when the primary objective is to describe geomagnetic polarity stratigraphy for cores 1A and 1B.

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RC: Line 10-15, Where in the stratigraphy are the samples that are not well behaved? Do they effect interpretation of polarity, either reversals or for short duration events?

AC: In case the interpretation of major reversals or geomagnetic 'events' would be compromised by problematic samples, this would naturally be discussed in the text. There are several places in the stratigraphy where paleomagnetic directions appear scattered. Most often these coincide with coarse grained basal parts of mass movement deposits or where sediment drilling experienced troubles. For the final composite such intervals were largely omitted (see Nowaczyk et al., 2013).

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RC: Line 15-17, it would be great if there was figure showing the MAD values. A stratigraphic view of the quality of the magnetization is important

AC: Plots showing MAD values for the core 1A, 1B and 1C are included now.

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RC: Line 19-21, “values might be equivocal.” Are those samples considered or not?

AC: ChRM data was not filtered in any way. All the available data is presented for cores

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1A, 1B and 1C.

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RC: Line 23-25, “Only the inclination of the ChRM will be discussed here” it does not mean that you cannot use declination to help your determination of when you go from one stable polarity to the next.

AC: We restrict ourselves to consideration of inclination data only, because the individual core sections (length 1 m, or less) are not azimuthally oriented. Because the site under investigation is located on high latitudes, inclinations are steep (about $\pm 80^{\circ}$) and do not pose problems when locating polarity transitions.

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RC: A better approach would be to define polarity transitions with an interval rather than just a depth, as there is uncertainty in the determination and polarity transition do take time.

AC: Yes, this would be one approach. However, we prefer expressing transitions with a finite depth value, which is a common approach. In addition, sedimentation rates are quite low in the upper 150 m ($\sim$ 4 cm kyr-1), comprising the past 2.8 Ma. Thus, a reversal is documented across only a few cm.

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RC: Page 5088, line 12-14 “data are partly unreliable because” You could use gray in the figures (instead of black or white) to denote intervals of indeterminate polarity.

AC: Corrected

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RC: Line 18, Are ages from Ogg and Smith (2004) consistent with those derived using LR04? Not an issue until you compare results, but could be important at that point.

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AC: Different sources report slightly different ages for reversals and shorter-lived features of the geomagnetic field. During the time interval covered by Lake El'gygytgyn sediments, Lisiecki and Raymo (2005) mostly report a few ka older reversal ages than Ogg and Smith (2004). The largest age difference between LR04 and Ogg and Smith (2004) is that of M/G boundary, where difference is as much as 27 ka (more than one precessional cycle). LR04 by Lisiecki and Raymo (2005) is used to date major reversal boundaries, because different climate proxies determined from the sediments of Lake El'gygytgyn are tuned with respect LR04 or Northern Hemisphere insolation variations. Only the ages for Cobb Mountain cryptochron and Reunion cryptochron are derived from Ogg and Smith (2004).

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RC: Line 23-25, "which may represent the Olduvai precursor" down core rock magnetic evaluations are required to evaluate the fidelity of these important features. There are other features (below the Brunhes/Matuyama boundary) in the inclination record that are not considered, so why should they be considered to be robust and not an artifact of coring induced overprints, disturbance, rock magnetic complexity, etc.

AC: Downcore rock magnetic measurements were not possible, because sediments enclosed in u-channels represent a kind of sediment archive and not to be sampled for rock magnetic analyses. Moreover, the current study was not designed to be a detailed rock magnetic study. At least, the precursor is consistently documented in two parallel cores within undisturbed sediment sequences.

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RC: Page, 5089, line 1 "These represent either sediment disturbances and/or coarse grained mass movement" This is not an either or question, so which is it?

AC: In a way it is an either-and/or issue. From a paleomagnetic point of view the coarse grained basal parts of mass movement deposits can sometimes be considered as sediment disturbances. However, not all sediment disturbances are related to mass movement deposits, but for example to issues during sediment drilling.

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RC: Line 18 “vaguely determined” If error bars were used or an interval to define transitions, vaguely would have a meaning.

AC: ’Vague’ refers to the unclear character of paleomagnetic data, which does not allow determining accurately termination of Kaena subchron. Using the word ’vague’ does not require use of error bars or other statistical presentation.

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RC: Section 4.3, wonder if this section that builds upon prior work (or at least it should) might be better prior to the magnetic polarity results?

AC: Section 4.3 ’Carrier of remanence in lake sediments an its origin’ is placed after polarity interpretations because mineral magnetic discussion is of lower priority with respect to polarity. With the available low resolution mineral magnetic results it is hardly possible to make detailed inferences of the possible implications of mineral magnetic variability to the reliability of magnetostratigraphical interpretation.

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RC: Page 5091, line 18-20 “comparable to that generally found in igneous rocks” this only applies to the high intensity intervals, which are only separated by a few meters from low intensity intervals and therefore not a general comment about the amount of magnetite.

AC: As already written in the text, we are not comparing the concentration of magnetic minerals present in source rocks to that in lake sediments. We merely state that concentration of magnetic minerals found in Lake El’gygytgyn catchment is comparable to that usually found in igneous rocks, which is a valid statement.

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RC: Line 25- “The variable lithology and the variable degree of physical and chemical alteration of the investigated source rocks is reflected in the highly variable concentration of magnetic minerals in the analyzed rock samples, and it is also characterized by magnetic susceptibility vs. SIRM bi-plot, which visualizes variations in the mineralogy, concentration, and grain size of magnetic minerals (Fig. 10).” This is the crux of the issue, should be stated and dealt with earlier in the manuscript and why care needs to taken for the magnetic stratigraphic interpretations that are based on the assumption that the magnetization accurately reflects the behavior of geomagnetic field at about the time of sediment deposition. In addition, this contradicts previous work and as stated a couple of pages below “However, as shown by Nowaczyk et al. (2007) and Murdock et al. (2013) using pilot cores from Lake El’gygytgyn, the concentration of magnetite in sediments is mainly controlled by the hypolimnetic redox conditions through large-scale magnetite dissolution during glacials and not simply by detrital input.” Page 5093, Line 20-24, Again the question is, does this influence the magnetic stratigraphy.

AC: We are presenting magnetic results measured from catchment rocks. Rock samples collected from colluvium and bedrock show variable magnetic characteristics, because there are several different rock types present in the catchment of Lake El’gygytgyn. Then again, climatically controlled changes in redox conditions and the associated magnetite dissolution in lake bottom are another issue. Is Referee trying to say here that the physical and chemical weathering under different climatic regimes (glcial-interglacial) affects characteristics of magnetic minerals entering the lake, which explains (partly) cyclical variations in MS in sediments? Question to the Referee: What suggests otherwise that magnetization does not record the magnetic field configuration approximately at the time of sediment deposition? The following comment touching this subject has been added to 5. Discussion:

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RC: Page 5092, line 1-5 “Smaller magnetite grains are: : : ” Take a look at Ozdemir et al., 1993 and Smirnov and Tarduno, 2000 for an alternative interpretation.

AC: Özdemir et al. have published 2 papers in 1993. We assume the Referee refers to ’The effect of oxidation on the Verwey transition in magnetite’ published in Geophysical Research Letters. The aforementioned paper discusses low-temperature magnetic measurements of near stoichiometric magnetite and maghemite of known grain size and the observed changes in Vervey transition, which they use as a tool to detect maghemitization. We do not have low temperature magnetic measurement data from our samples, so direct comparison of our results to Özdemir et al. (1993) is not possible. A literature survey of available magnetic data regarding iron oxides and -sulphides and their magnetic characteristics (concentration, mineralogy and grain size) by Peters and Dekkers (2003) support our interpretation of grain-size dependence of SIRM in titanomagnetite and magnetite. Smirnov and Tarduno (2000) also use low-temperature magnetic measurements to detect maghemitization of primary magnetite and dissolution of maghemitized coatings below Fe redox boundary in marine pelagic sediments. While low-temperature analyses appear to be attractive for the study of low-temperature oxidation of magnetite, they are not included in the present study, because the main objective is to reconstruct magnetostratigraphy to serve dating purposes. Low temperature magnetic measurements may be included in future work.

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RC: Line 6-15, The discussion here is based on an assumption that the magnetic separation and SEM work being illustrative of the dominant process, not just a process that is going on. These methods are often biased towards larger grain-sizes so advocating such a complex method as the reason why the hysteresis data suggest smaller grain sizes may not be justified.

AC: The following comment has been added to paragraph “4.3 Carrier of remanence in lake sediments and its origin”: It is also possible that the rather crude method of magnetic extraction for SEM/EDS microscopy may not produce a representative sample of the magnetic assemblage present in creek sediments.

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RC: Line 26-30, "Interestingly: : :" SIRM/κlf is not often thought to be a magnetic grain-size ratio and especially when dealing with maghematization as that typically gives higher SIRM values (Ozdemir et al., 1993 and Smirnov and Tarduno, 2000). ARM/klf is an alternative for grain-size that would be worth looking at.

AC: Question to the Referee: please explain why SIRM/klf is not 'often' thought to reflect magnetic grain size? To our knowledge SIRM/klf is widely used as granulometric indicator in environmental magnetic studies. This is not to say that interpretation of this interparametric ratio would be simple and straightforward in every case owing to the often complex natural magnetic assemblages and processes affecting them. A good approach would be to compare different granulometric indicators, such as ARM/SIRM, ARM/klf and SIRM/klf, but since we do not have ARM data from catchment rock samples, we will need to restrict ourselves to examining SIRM/klf only.

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RC: Page 5093, line 6-8 ".. a quarter of" the "samples indicate more pronounced contributions from magnetic minerals with harder coercvity: : :" might this reflect changes in magnetic concentration, with the hematite more apparent during intervals influence by reductive diagensis and reduced magnetite contribution as stated below. "However, as shown by Nowaczyk et al. (2007) and Murdock et al. (2013) using pilot cores from Lake El'gygytgyn, the concentration of magnetite in sediments is mainly controlled by the hypolimnetic redox conditions through large-scale magnetite dissolution during glacials and not simply by detrital input." Page 5093, Line 20-24, Does maghemite survive in the reduced intervals and how do these influence magnetic polarity boundaries or do they influence magnetic polarity boundary determination?? Overall, suggest they focus on the lake sediments. Its nice that they show that these sediments are gen-

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erally consistent with a detrital origin, but more than that is really not relavent to the main point of this paper being magnetic stratigraphy. Therefore suggest that some of the discussion of the processes and differences between lake and catchment magnetic properties be placed elsewhere.

AC: We don't think that mineral magnetic data from lake sediments (measured from core catcher samples), creek sediments and catchment rocks should be placed elsewhere just because we cannot discuss them directly in terms of magnetite dissolution...

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RC: Page 1094, line 15- "These magnetostratigraphic tie points form the chronological frame for aligning (tuning) the different sediment climate proxy parameters with respect to orbital changes, which refines the temporal resolution of the sediment chronostratigraphy (Nowaczyk et al., 2013)." This illustrates the importance of getting this right and the care that should be taken with our assumptions of the age of magnetic reversals, there durations and there positions relative to isotopic stages which is clearly a work in progress (see Channell et al., 2010 for a good example).

AC: Our magnetostratigraphic interpretation and tuning of different proxy parameters measured from sediments from Lake El'gygytgyn has been executed with the information presently available.

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RC: Page 1097, line 20- "the position of lake El'gygytgyn may decrease" There are a myriad of reasons for why something might not be recorded, but a longer duration for reversals is likely not one of those as that would have the opposite effect.

AC: We believe the Referee has misunderstood the point that we make. We write on Page 5097, lines 20-23: "In addition to low sedimentation rates, the position of Lake El'gygytgyn may decrease the probability of very short-term geomagnetic changes of being recorded, because polarity change is anticipated to take a longer time at high

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latitude sites compared to lower latitudes (Clement, 2004)". According to simple geometrical models describing polarity reversals, shorter durations are observed at low-latitude sites whereas longer durations are observed at mid- to high-latitude sites. In case it takes more time for a full polarity reversal to take place in higher latitudes, it is less probable that short geomagnetic events would be recorded there.

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RC: Line 24, what is the rock magnetic variability around these?

AC: On Page 5085, lines 2-4 we state: 'While sediments sampled in u-channels were considered as archival material, sediment enclosed in core catchers, one in every three meters of sediment, from the cores 1A to 1C was available for a mineral magnetic investigation.' We do not have mineral magnetic results from these sediment intervals.

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RC: Line 26, "more scattered inclination record" What about the quality of the cored material, there is little discuss about that and coring disturbance along with drill string induced overprints are common reason to have low quality results associated with deeply buried materials.

AC: On page 5082, lines 2-5 we write: 'Rather long intervals in core 1C were hampered by incomplete sediment recovery (Table 1), which may be related to coarse sediment intervals encountered at this part of the sequence and/or the coring tool employed (Melles et al., 2011).' Technical issues during drilling of core 1C and coarser-grained sediment intervals lead to poor core recovery in this part of the lake sediment sequence. No indication of drilling-induced magnetic overprints was observed.

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RC: Page 5098, line 8, "Remanence is carried by partly maghemitized titanomagnetite: : :" Whether this is consistent throughout the record is not well demonstrated. The fact that there are two populations of lake sediment on the day plot (Fig. 11) is not

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discussed and should be.

AC: A detailed characterization of magnetic mineralogy in the sediment column was not the main topic of the study. The following statement has been added to text: “Higher magnetic concentration during Pliocene is therefore interpreted to reflect thorough mixing of lake water column and weaker magnetite dissolution due to warmer Pliocene climate in the Arctic (Brigham-Grette et al., 2013).”

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RC: Tables 2 should include references 4, I would suggest against listing Intra-Jaramillo and Olduvai precursor in the same table as your polarity reversal boundaries as they cannot be used to provide age control, but are rather observations of potential geomagnetic features of interest. Also, I would suggest you come up with a # for the depth interval and if possible tie it to the core, section and interval depths.

AC: Intra-Jaramillo and Olduvai precursor have been removed from the table.

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RC: Figures. 2 Would be great to see intensity after at least one demagnetization step as well as the NRM and ideally this plot would also include inclination, declination and MAD values. 3 and 4, would be great if these were associated with representative lithologies (high and low intensity) and around intervals of interest as well as covering the core material. Nice if location from where these were taken were shown in Figure 2.

AC: Intensity decreases smoothly as shown by the representative samples in Fig. 4. We show ChRM calculated from several demagnetization steps and the associated MAD values, which is suggested by the Anonymous Referee. Showing intensity, I and D and MAD from single steps would not add information compared to what we already see. Samples/measurement intervals were equally chosen mainly from different polarity intervals (3 N and 3 R). The proximity of the two lowermost samples just shall show

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how clear normal polarity is expressed here, that there is no doubt that sediments were deposited in the lower Gauss chron, and not in the latest Gilbert, which is theoretically possible, according to the dating error given by Layer (2000). - - -

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RC: 5. Optimally VGP latitude, at least around transitions, should be calculated and polarity determinations based on that. Would be nice for the reader to have the GPTS shown as a panel along side. Blowup of the transitions would also provide the reader with a clearer understanding of the transitional interval and how precisely it is or is not defined

AC: In case there would be confusion with defining polarity transitions, that would be discussed in the text. Only onset of Mammoth chron and termination of Kaena remains less precisely defined, which is mentioned in the text. Since unoriented core section of 1 m length, or less, were used, and the horizontal component is quite small with respect to the vertical component at 67°N, it was not possible to re-orient core sections on basis of mean declinations. Thus, it was also impossible to calculate VGP position.

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RC: 11. Why does Parry (1980) line work better that Dunlop's updated versions

AC: Typically, the ratio Msr/Ms vs. Bcr/Bc is biased toward the right edge of the plot when hematite is present, so this feature is related to the characteristics of the magnetic minerals used by Parry to define his model curve. His samples "appear to be pure magnetite with only a non-magnetic gangue-mineral impurity". Possibly there was also some haematite in them, as there is in Lake El'gygytgyn sediments.

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