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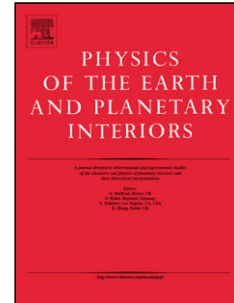
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1 **Upper and Lower Jaramillo polarity transitions recorded in IODP Expedition 303**
2 **North Atlantic sediments: implications for transitional field geometry**

3
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12
13 **Abstract:**

14 Sediments collected during the Integrated Ocean Drilling Program (IODP) Expedition 303
15 in the North Atlantic provide records of polarity transitions and geomagnetic excursions at a
16 high resolution. Here we investigate polarity transitions at the upper and lower boundaries of
17 the Jaramillo Subchronozone at Sites U1305, U1304, and U1306. The sediments carry
18 strong natural remanent magnetizations (NRM) with median destructive fields consistent
19 with magnetite as the dominant magnetic carrier. Both polarity transitions are characterized
20 by low values of relative paleointensity. The U1305 record of the lower Jaramillo reversal
21 exhibits a marked cluster of virtual geomagnetic poles (VGP) over southern South America,
22 and a secondary accumulation in the region of NE Asia / North Pacific. The main South
23 American VGP cluster is also visible at Site U1304, which documents a less complex
24 pattern, possibly because of a higher degree of smoothing. Records of the upper Jaramillo
25 polarity transition document a VGP loop over the Americas, followed by north to south
26 motion including a secondary VGP accumulation near India. The similarity between several
27 records of the upper Jaramillo transition obtained at various sites in the North Atlantic is a

28 strong indication that geomagnetic field changes have been faithfully captured. Results
29 suggest that a transverse, possibly dipolar, component has fluctuated during these polarity
30 reversals, and that these fluctuations combined with a reduced axial dipole component
31 yielded the observed field at the Earth's surface during the polarity transitions. The lower
32 Jaramillo transition also exhibits VGP clusters in the vicinity of South America and eastern
33 Asia but these clusters are shifted relative to the upper Jaramillo VGP clusters, implying a
34 memory exerted by the upper mantle on polarity transition geometry.

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36 **1 – Introduction**

37 Integrated Ocean Drilling Program (IODP) Expedition 303 was conducted in
38 September-November 2004, with the principal objective of exploring the millennial-scale
39 climate variability in the North Atlantic Ocean during the Quaternary and late Neogene.
40 Such studies require not only adequate sedimentation rates but also a viable means of long-
41 distance stratigraphic correlation at an appropriate resolution. In this respect, paleomagnetic
42 records, particularly records of relative paleointensity, provide the means of augmenting
43 more traditional stable isotope records. In addition, such studies provide information on the
44 high-resolution behavior of the geomagnetic field that can be utilized by geophysicists
45 investigating the geodynamo.

46 Sediments were obtained using the Advanced Piston Corer (APC), with non-
47 magnetic core barrels which limit magnetic overprint during the coring process [Lund et al.,
48 2003]. Many of the drilled sites are characterized by high mean Quaternary sedimentation
49 rates, of 15 –20 cm/kyr [Channell et al., 2006]. The high sedimentation rates, combined with
50 the fidelity of the natural remanent magnetization (NRM) records, provide the opportunity to
51 study the configuration and paleointensity of the geomagnetic field during polarity reversals.
52 The configuration of the transitional field at polarity reversals remains poorly documented
53 due to the paucity of sedimentary records with sufficient resolution to record these
54 millennial-scale processes, and the intermittent character of volcanic reversal records. Here,
55 we present results obtained at Sites U1304, U1305 and U1306 for the polarity transitions at
56 the top and base of the Jaramillo Subchronozone.

57

58 **2- Drilling sites and shipboard paleomagnetic results**

59

60 Sites drilled during the IODP Expedition 303 are described in detail in the IODP
61 Volume 303/306 Expedition Report [Channell et al., 2006]. At Site U1305, located at the
62 southwestern extremity of the Eirik Drift off southern Greenland (Lat 50°10'N, Long 48°31
63 W), three holes recovered sediments from the Brunhes and Matuyama Chronozones,
64 including the Jaramillo Subchronozone. Water depth at this site is 3460 m (Fig. 1) such that
65 the sediment-water interface is located below the present-day main axis of the Western
66 Boundary Undercurrent (WBUC). For this reason, and on the basis of oxygen isotope
67 stratigraphies from neighboring sites documenting the last glacial cycle, the site is likely to
68 be characterized by expanded interglacials and relatively condensed glacial stages. The base
69 of the section lies within the Olduvai Subchronozone at about 1.8 Ma with a mean
70 sedimentation rate of 17 cm/ kyr [Shipboard Scientific Party, 2006]. Sediments recovered at
71 the site comprise silty clays with nanofossils. Paleomagnetic measurements were
72 conducted shipboard on archive half core sections comprised measurements of NRM using
73 the shipboard pass-through cryogenic magnetometer. The spatial resolution of the shipboard
74 magnetometer, as measured by the width at half-height of the pickup coil response function,
75 is about 10 cm for each of the three orthogonal axes. Aboard ship, NRM intensity and
76 direction of half-core sections were measured before any demagnetization, and re-measured
77 after limited alternating field (AF) demagnetization, restricted to peak fields of 10 mT, or
78 occasionally 20 mT. Low peak demagnetization fields ensure that archive halves remain
79 useful for shore-based high-resolution measurements of u-channel samples. NRM intensities
80 before demagnetization range from $\approx 10^{-1}$ to more than 1 A/m. After AF demagnetization at
81 peak fields of 10-20 mT, intensities are reduced to $\approx 10^{-1}$ A/m. NRM inclinations vary
82 around the value expected for a geocentric axial dipole, for both normal and reverse polarity
83 intervals. Despite the limited AF demagnetization, the Brunhes and the upper Matuyama

84 subchronozones were clearly identified in shipboard records [Shipboard Scientific Party,
85 2006].

86 Site U1306 (Lat 58°14'N, Long 45°38'W) was drilled South of Greenland, in a water
87 depth of ≈ 2270 m in the main axis of the Western Boundary Undercurrent (WBUC).
88 Sediments comprise silty clays with varying amounts of diatoms, nannofossils and
89 foraminifera [Shipboard Scientific Party, 2006]. Based on stratigraphies for the last glacial
90 cycle obtained from conventional piston cores in the region, we expect glacial intervals to be
91 expanded relative to interglacials, providing a stratigraphy that is complementary to that
92 obtained at Site U1305. Shipboard paleomagnetic measurements revealed NRM intensities
93 prior to demagnetization in the 10^{-1} A/m range. After AF demagnetization at peak fields of
94 10 or 20 mT, NRM intensities were reduced by about 50%. Inclinations vary around the
95 expected values for a geocentric axial dipole for normal and reverse polarity intervals. The
96 Brunhes Chronozone and the upper Matuyama subchronozones were clearly identified from
97 shipboard magnetic measurements [Shipboard Scientific Party, 2006].

98 Site U1304 (Lat 53°03'N, Long 33°32' W) was drilled at the southern edge of the
99 Gardar Drift in a water depth of ≈ 3065 m. The objective was to compare climatic and
100 paleomagnetic records to those previously obtained on the northern part of the Gardar Drift
101 during ODP Leg 162 (Site 983). Sediments at Site U1304 comprise interbedded diatom
102 oozes and nanofossil ooze with intervals of clay and silty clay. Shipboard paleomagnetic
103 measurements document NRM intensity in the range of 10^{-1} A/m for most intervals.
104 Intervals rich in diatom oozes are less strongly magnetized with intensities in the range of
105 10^{-3} A/m. An almost continuous sequence was obtained including the Brunhes Chron and
106 part of the Matuyama Chron, including the Jaramillo and Cobb Mountain Subchronozones,
107 and the top of the Olduvai Subchronozone [Shipboard Scientific Party, 2006].

108

109 **3 Sampling and laboratory methods**

110

111 Core sections from IODP Sites U1304, U1305 and U1306 recording geomagnetic
112 polarity transitions and excursions were sampled with u-channels at the IODP core
113 depository in Bremen (Germany) in February 2005 prior to the main sampling in May 2005.
114 The objective was to measure polarity transitions in u-channels from the working halves of
115 core sections that would later be sub-sampled for other purposes during the main sampling
116 party three months later. Natural remanent magnetization (NRM) and bulk magnetic
117 parameters were measured at a high-resolution with pass-through cryogenic magnetometers
118 designed for long-core measurements [Weeks et al., 1993] at the LSCE in Gif-sur-Yvette
119 (France) and at the University of Florida, Gainesville. Stepwise AF demagnetization of the
120 NRM was conducted up to peak fields of 100 mT using the in-line 3-axes AF coils system.
121 Component magnetization directions were then determined for the 20-60, or 20-80 mT
122 demagnetization interval using the standard “principal component” method of Kirschvink
123 (1980) either through the standard software used at the University of Florida, or through the
124 Excel routine used at Gif-sur-Yvette [Mazaud et al., 2005]. Declinations of the resolved
125 component magnetizations were adjusted according to the shipboard "Tensor Multishot"
126 orientation tool when available, or by uniform rotation of cores such that the core mean
127 declinations for intervals outside the polarity transitions equaled 0° or 180° , depending on
128 the sign of the inclination.

129 After measurement of NRM, the following magnetic concentration parameters were
130 measured on all u-channels: volume low-field susceptibility (κ), anhysteretic remanent
131 magnetization (ARM), and the isothermal remanent magnetization (IRM). κ is controlled by
132 the amount, nature and grain size of ferromagnetic (s.l.) and is also influenced by
133 paramagnetic and diamagnetic minerals. ARM and IRM, on the other hand, are remanent

134 magnetizations, and therefore solely sensitive to the ferromagnetic (s.l.) fraction, and do not
135 depend on paramagnetic minerals. ARM is principally linked to small magnetic grains, with
136 size around 0.1 – 5 μm , while IRM is sensitive to a wider spectrum of grain sizes up to
137 several tens of microns [Maher, 1988; Dunlop and Ozdemir, 1997]. ARM was acquired
138 along the axis of the u-channel using a 100 mT AF field and a 50 μT DC field. It was
139 demagnetized using the same steps than those used for the NRM. IRM was acquired in 6
140 steps up to 1 T using a 2G pulsed IRM solenoid. $\text{IRM}_{1\text{T}}$ was stepwise demagnetized. Then,
141 after a re-acquisition at 1 T, a backfield of 0.3 T was applied to calculate the S-ratios_{0.3T} ($S_{0.3\text{T}} = -\text{IRM}_{0.3\text{T}}/\text{IRM}_{1\text{T}}$. [King and Channell, 1991]), which provides a measure of magnetic
142 coercivity spectrum that can also be gauged by hysteresis experiments conducted with a
143 Princeton Measurements Corp. alternating gradient magnetometer (AGM) or vibrating
144 sample magnetometer (VSM). Measurements of the low field bulk susceptibility (κ) were
145 performed using a small diameter Bartington sensor loop mounted in line with a track
146 system designed for u-channels at Gif-sur-Yvette and a Sapphire loop with susceptibility
147 track designed for u-channels at the University of Florida [Thomas et al., 2003].
148

149

150 **4. Records of polarity transitions**

151

152 *4.1 Lower Jaramillo transition*

153 The lower Jaramillo polarity transition is recorded in the composite section at Site
154 U1305 [Shipboard Scientific Party, 2006] between 167 and 169 meters composite depth
155 (mcd). Orthogonal projections of AF demagnetization data indicate progressive decrease of
156 NRM intensity at peak fields greater than 20 mT (Fig. 2a). Component magnetization
157 directions were calculated for the 20 to 60 mT AF peak field interval (Fig. 2b and 2c)
158 Maximum angular deviations (MAD) values [Kirschvink, 1980] (Fig. 2d) indicate the

159 precision of the definition of magnetization components. Median destruction fields of about
160 27 mT is obtained for ARM, which is consistent with magnetite or low Ti (titano)magnetite as
161 the dominant carrier of the NRM. NRM/ARM is a proxy commonly used for relative
162 paleointensity determinations [Banerjee and Mellema, 1974; Levi and Banerjee, 1976; King
163 et al., 1983; Tauxe, 1993]. Here we used the NRM-ARM slope calculated in the 20-60 mT AF
164 peak field range [Channell et al., 2002]. The linear correlation coefficient (r) indicates well-
165 defined slopes with values around 0.99 outside the transition and higher than 0.95 during the
166 reversal (Fig. 2i). The NRM/ARM slopes indicate a broad low at the time of directional
167 changes associated with the polarity transition. Interestingly, the paleointensity was
168 significantly reduced prior the directional reversal (Fig. 2i). Virtual geomagnetic poles
169 (VGPs) were then calculated from the NRM component directions. The plot of VGPs (Fig.
170 2g) is used here as a convenient means of documenting directional changes at the reversal (in
171 addition to Figs. 2 b-d), and does not imply that the transitional fields were dipolar. VGP
172 latitudes fluctuate prior the transition in the 168.5-169.6 mcd interval (Fig. 2h), however,
173 these fluctuations occur in an interval where the bulk magnetic parameters (κ , ARM, IRM and
174 ARM/ κ) also fluctuate around relatively high values (Fig. 2e). The polarity transition onset at
175 about 168 mcd is marked by an accumulation of VGPs over the South America. The VGP
176 then moves to the northern hemisphere, with a large longitudinal drift and a secondary
177 accumulation of VGPs over eastern Asia (Fig. 2g).

178 Another record of the same transition was obtained at Hole U1304B at ≈ 176 mcd
179 (Fig. 3). Stable magnetization components were isolated after AF demagnetization at peak
180 fields of ≈ 20 mT (as before component magnetization directions were calculated in the 20-60
181 mT peak field range). Bulk magnetic parameters display very limited variations, indicating
182 that, in this case, the paleomagnetic record is not strongly perturbed by changes in
183 concentration and grain size of the magnetic fraction. A broad low in relative paleointensity

184 (NRM-ARM slope) coincides with the directional transition (Fig. 3i). No fluctuations are
185 observed prior the transition. However, only a limited interval prior to the transition was
186 sampled. This VGP path shows a less complex pattern than at site U1305. This could be due
187 to more smoothing of the transition record at Site U1304 than at Site U1305. A VGP cluster
188 near southern America is apparent at the onset of the polarity transition. The VGP motion to
189 the northern hemisphere resembles that obtained at Site U1305. No longitudinal drift of the
190 VGP is visible in the last part of this record of the lower Jaramillo transition.

191

192 *4.2. Upper Jaramillo transition*

193 This polarity transition is recorded between ≈ 156 and 158 mcd at Hole U1305A (Fig.
194 4). AF demagnetization indicates that a stable magnetization component is resolved after ≈ 20
195 mT peak field demagnetization. As for the other transitions, the characteristic NRM directions
196 were calculated for the 20-60 mT peak field range, and MAD values were calculated.
197 Fluctuations of the bulk magnetic parameters are very limited in the vicinity of the transition,
198 suggesting that magnetic concentration and grain size were more uniform for the upper
199 Jaramillo transition than for the lower Jaramillo transition at Site U1305. NRM-ARM slopes
200 are well defined (Fig. 4i) and they indicate reduced field intensity at the time of directional
201 changes. VGP motion starts from the North pole with a large loop over the Americas,
202 followed by a progressive move from the North pole to the South pole that includes a
203 secondary accumulation of VGPs at low latitudes in the Indian Ocean. A short post-
204 transitional excursion is observed at ≈ 155.5 mcd (Fig. 4).

205 Record obtained at Hole U1306D (Fig. 5) offers a very detailed view of the same
206 transition trajectory, with a transitional zone over more than 2 m. As for Hole 1305A, stable
207 component was isolated after 20mT peak alternating field demagnetization. Characteristic
208 NRM directions were calculated for the 20 - 80 mT peak field range, and are clearly defined

209 through the entire transitional zone. NRM-ARM slopes indicate a broad low in relative
210 paleointensity which coincides with the directional reversal (Fig. 5). Magnetite abundance
211 and grain size proxies document limited variability and do not correlate with characteristic
212 NRM directions or intensity changes (Fig. 5). Overall, the VGP trajectory calculated from the
213 characteristic directions (Fig. 5) is very similar to that of Site U1305, with a large VGP swing
214 over the Americas prior a pole-to-pole transition showing a secondary cluster (Fig 5).

215 Finally, another record of the Upper Jaramillo transition was obtained at Hole U1304B
216 in the 164 and 165 mcd interval (only a limited interval around this transition was sampled).
217 ARM, IRM, χ and ARM/ χ (Fig. 6) indicate homogeneity in amount and size of magnetite
218 grains. The VGP path calculated from the characteristic NRM directions is less complex than
219 at Sites U1305 and U1306 (Fig 6), presumably because of a higher smoothing of the polarity
220 transition at this site. Nevertheless, a strong resemblance with the records from sites U1305-
221 U1306 records is observed. Records at sites U1305 and U1306 are remarkably similar to the
222 record previously obtained at ODP Site 983 (ODP Leg 162) [Channell and Lehman, 1997]
223 (Fig. 7). Overall, the similarity between several records obtained at various sites in the North
224 Atlantic is a strong indication that geomagnetic field changes during this transition were
225 correctly captured.

226

227

228 **5- Discussion and conclusion**

229

230 Detailed records obtained for the upper and lower Jaramillo polarity transitions from
231 IODP Expedition 303 sediments yield VGP trajectories (Fig. 7) that show clusters and loops
232 alternating with fast changes, reminiscent of reversal records previously obtained at ODP
233 Sites 983 and 984, and also of some volcanic records [Channell and Lehman, 1997; Mazaud

234 and Channell, 1999, Channell et al., 2004; Prévot et al., 1985; Mankinen et al., 1985]. The
235 VGP paths do not pass close to the sites or to their antipodes, confirming the idea that the
236 transitional fields are not axi-symmetric. Clusters and loops tend to be located in the two
237 longitudinal bands, one over eastern Asia and another over the Americas, that were
238 recognized over 15 years ago in sedimentary and volcanic records and interpreted to indicate
239 lower mantle influence on transition field geometry [Clement, 1991; Laj et al., 1991;
240 Hoffman, 1992; Love, 1998]. Other causes linked to sedimentary magnetization acquisition
241 rather than to geomagnetic field behavior have been also envisaged for these two bands
242 [Quidelleur et al., 1995]. Such artifacts, however, are hardly compatible with the complex
243 patterns obtained here. In the higher resolution (higher sedimentation rate) records
244 illustrated here, VGPs appear to jump from one longitudinal band to the other during an
245 individual polarity transition.

246 The similarity between the different records of the upper Jaramillo transition
247 obtained at North Atlantic sites (ODP Sites 983 and 984, and IODP Expedition –303) is a
248 convincing indication that geomagnetic field changes were faithfully captured at these sites
249 (Fig. 7). Transitional VGPs obtained for the upper Jaramillo transition tend to be located in
250 the two preferred longitudinal bands, with a VGP loop over the Americas prior an eastern
251 Asia VGP path with a secondary VGP accumulation, and, finally, in some records, a VGP
252 loop in the vicinity of Australia (Fig. 7). The results suggest a simple mechanism, in which a
253 transverse field, possibly dipolar, has oscillated while the axial dipole was reduced in
254 intensity. In this scheme, the transverse component and a residual axial dipole alternatively
255 dominate the field during the transition. When the intensity of the transversal component is
256 strong, then VGP departs from the pole and moves towards low latitudes. When the
257 transverse component is weak, then VGP moves back towards the north, or south,
258 geographic pole, because of the dominance of the axial dipole term. The initial excursion

259 visible in the upper Jaramillo transition records is consistent with a transversal field growing
260 and then decaying in intensity, while the residual axial dipole does not strongly change.
261 After this loop, the VGPs move to a final reverse polarity along a longitudinal path
262 approximately antipodal to the initial loop (Fig. 7). A transversal field opposed to that
263 responsible for the initial loop may explain this feature, suggesting an oscillation between
264 two opposite configurations. This simple scheme is somewhat reminiscent of the field
265 evolution during geomagnetic excursions, for which an important role for a transversal
266 dipole field has been proposed [Laj et al., 2006; Laj and Channell, 2007]. A model relating
267 VGP path longitude, site location, and motion of magnetic flux patches at the core surface
268 has been proposed [Gubbins and Love, 1998]. A western VGP path (i.e. near the Americas)
269 is expected for a N-R reversals recorded in the north Atlantic, when a pole-wards motion is
270 hypothesized for the flux patches [Gubbins and Love, 1998]. The initial loop over or near
271 the Americas for the upper Jaramillo polarity transition may fit this scheme. During this
272 loop, VGP departure from the North pole and subsequent return to the same pole occurred
273 along almost identical longitudes (Fig. 7), which suggests a reversible evolution of the
274 geomagnetic field, and therefore of the flux patches in the scheme of Gubbins and Love
275 [1998]. Another configuration, however, has to be envisaged for the final VGP motion to the
276 South pole, which occurred at a longitude approximately antipodal to that of the initial loop
277 (Fig. 7). The lack of a precise age model does not allow investigation of the tempo of the
278 geomagnetic field changes during the Jaramillo polarity transitions. At Site U1305, it is
279 observed that the extremity of the initial loop and the secondary VGP accumulation in the
280 final motion to the South pole over Indian Ocean are separated by about 20 cm in the
281 sediment record (Fig. 4). This interval corresponds to about 1 kyr, assuming that the overall
282 mean sedimentation rate at this site can be applied to this interval. This is of the order of
283 theoretical estimates [Hulot and Le Mouél, 1994] for transverse dipole fluctuations in the

284 modern field. At ODP Sites 983 and 984, the records of polarity transitions for the upper
285 Olduvai [Mazaud and Channell, 1999] and for the Brunhes-Matuyama boundary and
286 Jaramillo reversals [Channell and Lehman, 1997; Channell et al., 2004] also exhibits a VGP
287 loops that feature south American and east Asian VGP clusters that suggest a similarity
288 between these two successive reversals implying a memory for the transition field geometry
289 imparted by the influence of the lower mantle. The importance of heat flux across the core-
290 mantle (C-M) boundary in controlling reversal rates in numerical models [Glatzmeier et al.,
291 1999], implies that the C-M heat flux is an important control on transition field geometry.
292 Progressively, high-resolution sedimentary and volcanic records of polarity transitions are
293 converging towards a consistent picture of the geomagnetic field evolution during polarity
294 transitions.

295

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302

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409 **Figures:**

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415 Figure 1. Location of IODP Sites U1304, U1305 and U1306 in the North Atlantic.

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417 Figure 2. Results obtained for the Lower Jaramillo transition at Hole U1305A a) Typical
418 diagrams of AF demagnetization (Orthogonal projection, open and full circles: inclination,
419 and declination, axes unit: 10^{-6} A/m; some AF demag levels are also indicated along the
420 graphs), b) ChRM declination, c) ChRM inclination, d) MAD, e) ARM and κ , (left scale)
421 and IRM (right scale), f) ARM/k, g) VGP plot (Hammer-Aitoff projection); in gray pre-
422 transitional fluctuations for which a geomagnetic origin is uncertain, see text, h) VGP
423 latitude, i) NRM versus ARM regression values. In the different diagrams, mcd means
424 meters below seafloor.

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427 Figure 3. Results obtained for the Lower Jaramillo transition at Hole U1304B (see Fig. 2 for
428 caption details

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430 Figure 4. Results obtained for the Upper Jaramillo transition at Hole U1305A (see Fig. 2 for
431 caption details)

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434 Figure 5. Results obtained for the Upper Jaramillo transition at Hole U1306D (see Fig. 2 for
435 caption details)

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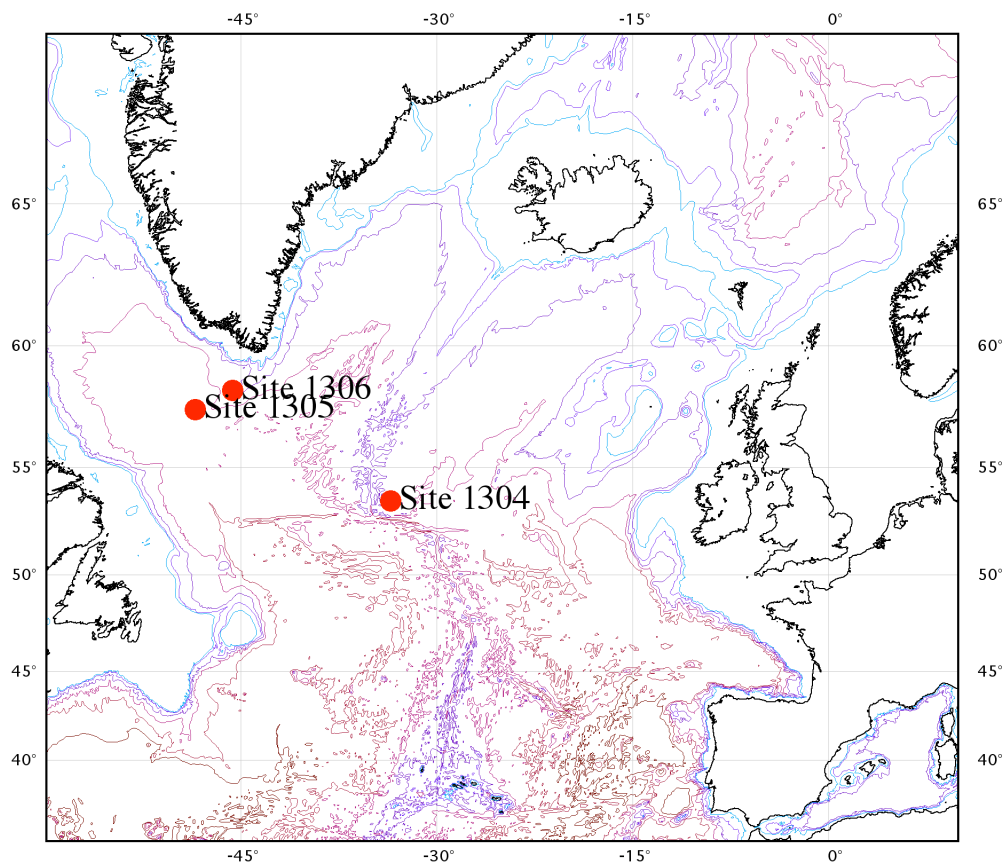
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438 Figure 6. Results obtained for the Upper Jaramillo transition at Hole U1304B (see Fig. 2 for
439 caption details)

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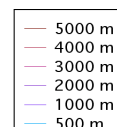
441 Figure 7. Summary of the detailed VGP paths obtained for the Upper and Lower Jaramillo
442 transitions. Records of the Upper Jaramillo and Upper Olduvai transitions previously
443 obtained at site 983 (ODP-162) are also shown [Channell and Lehman, 1997; Mazaud and
444 Channell, 1999]. Orange circles indicate VGP loops and accumulations.

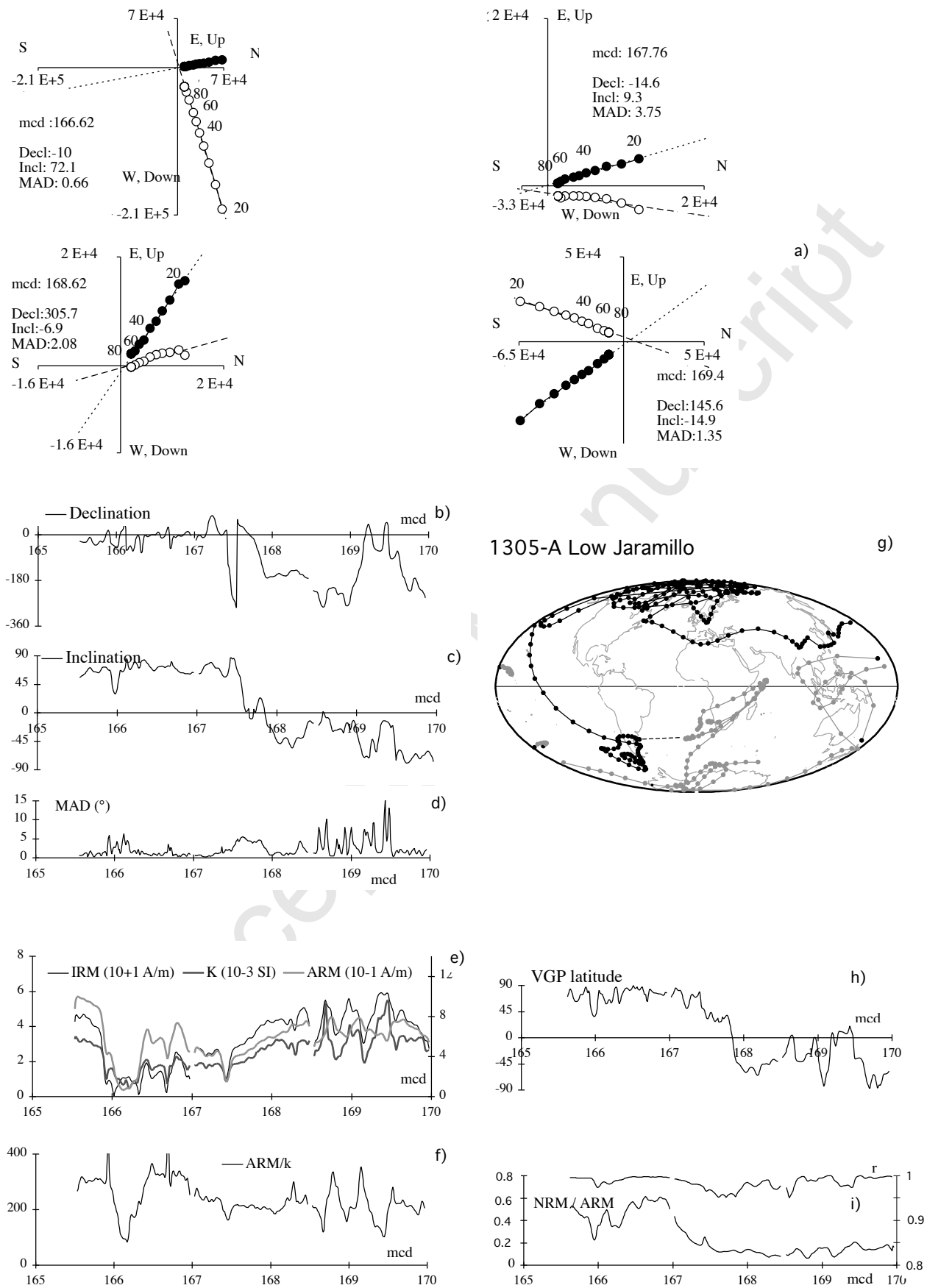
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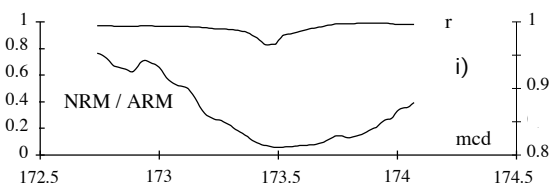
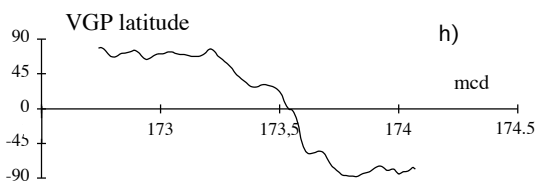
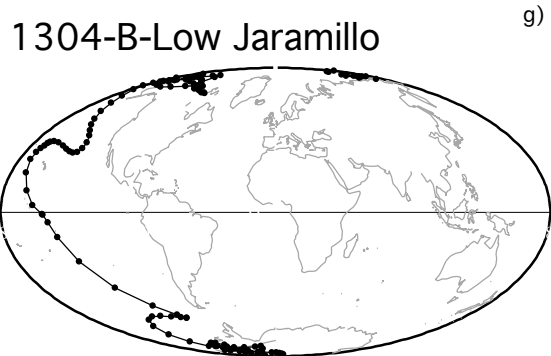
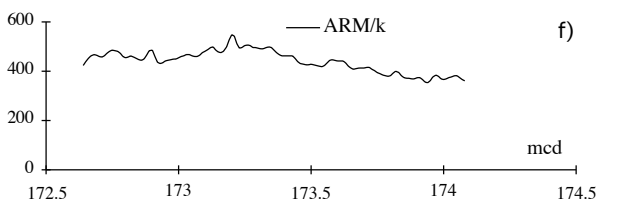
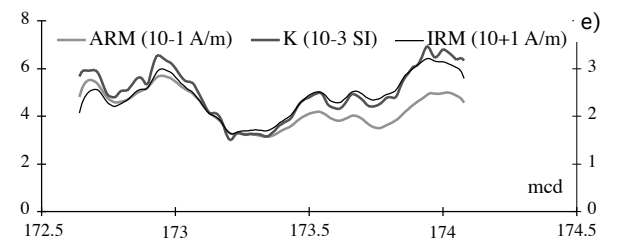
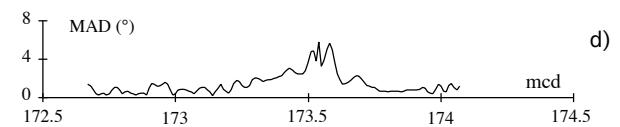
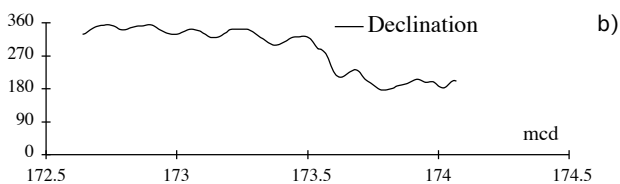
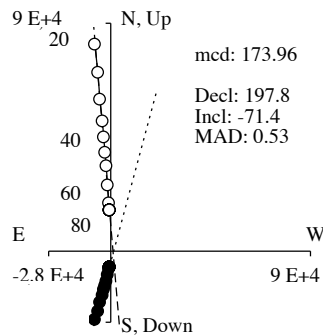
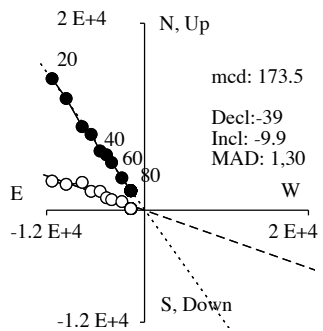
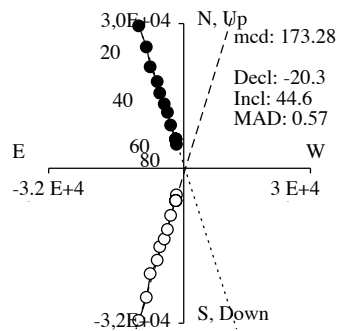
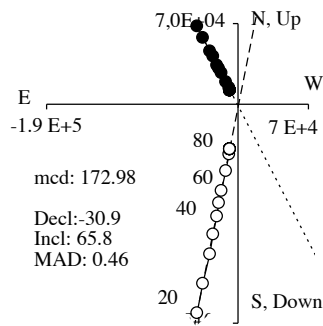


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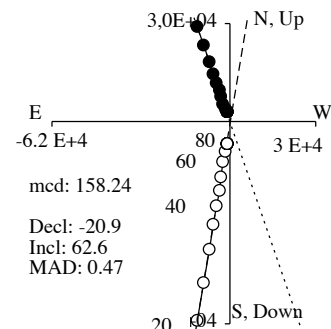
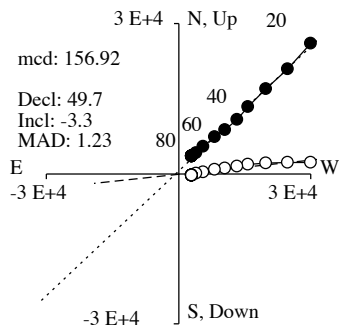
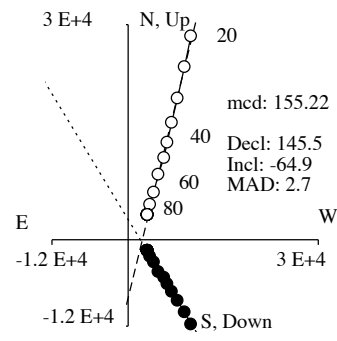
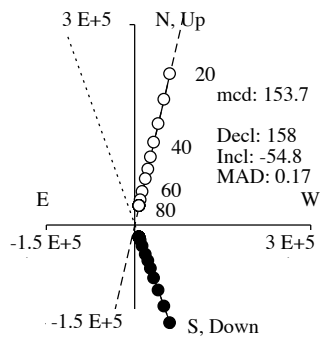




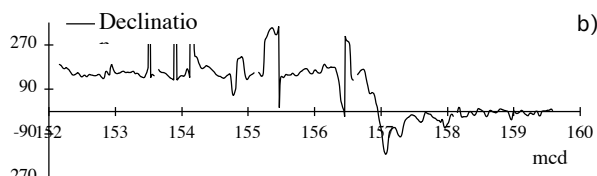


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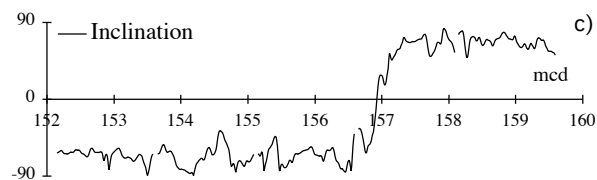
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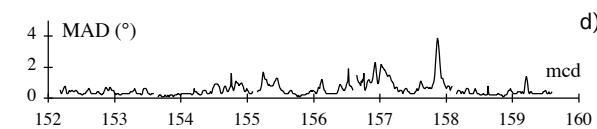
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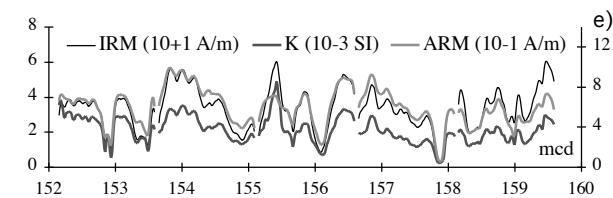
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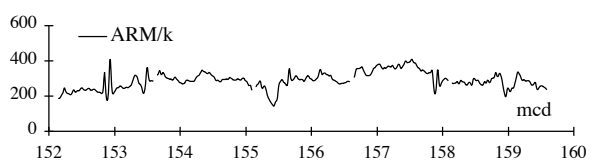
c)



d)



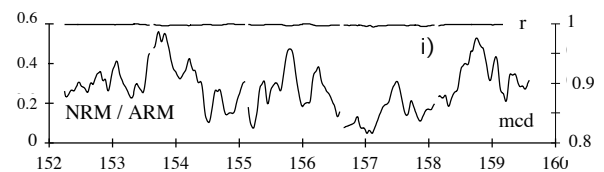
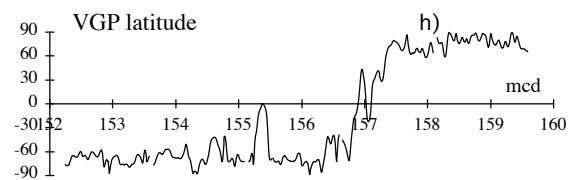
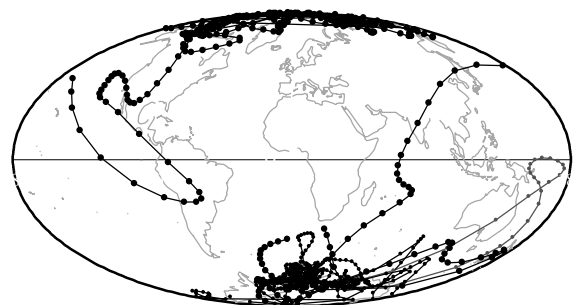
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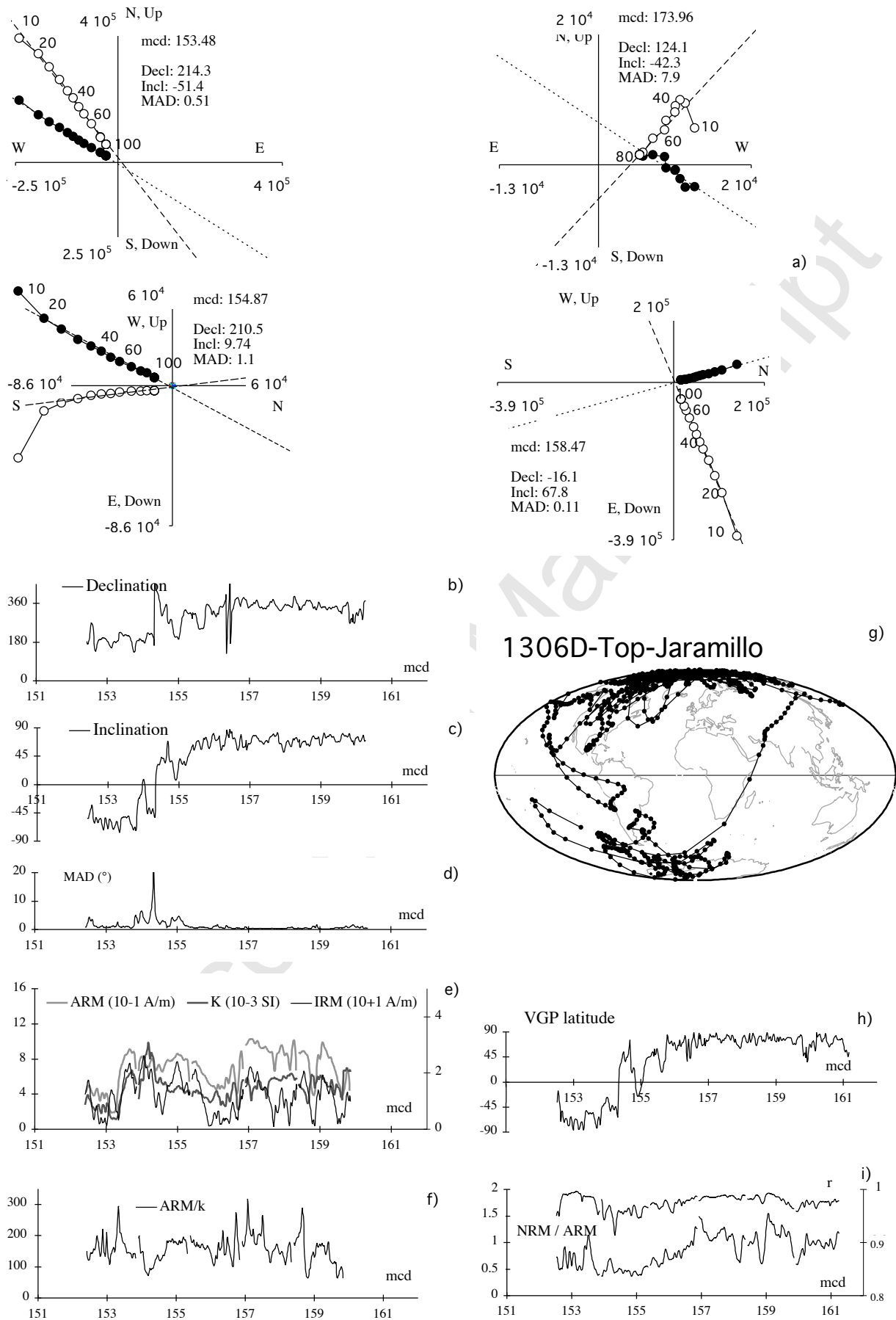


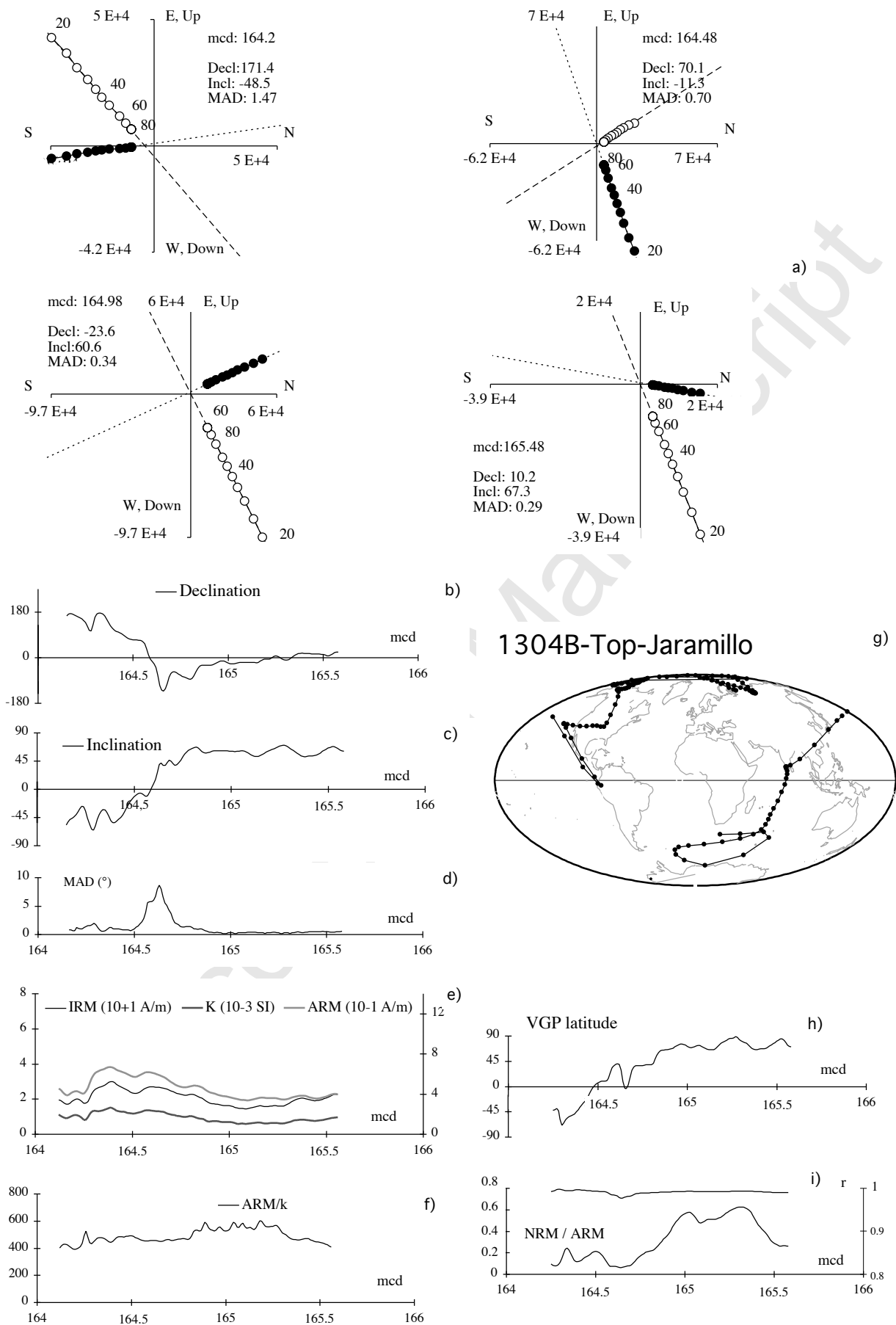
f)

1305-A-Top Jaramillo

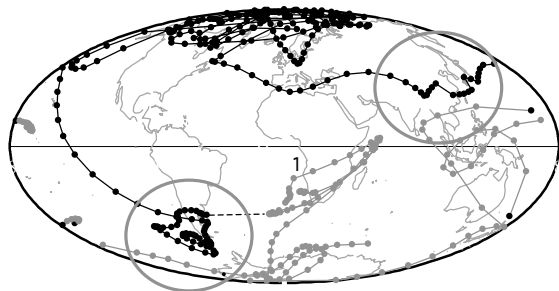
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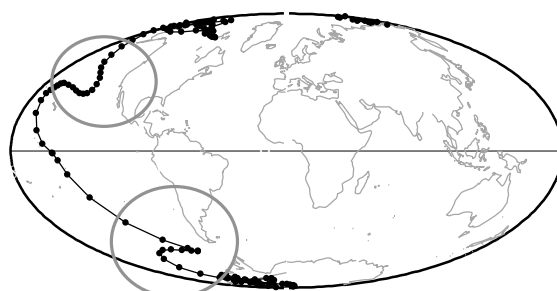




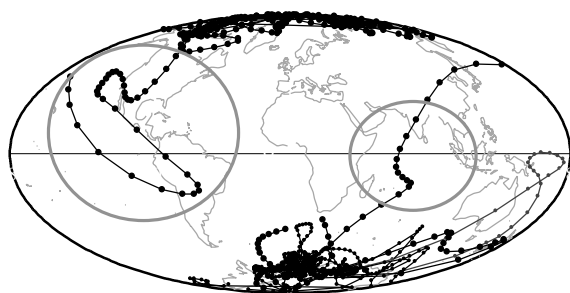
a) 1305A lower Jaramillo



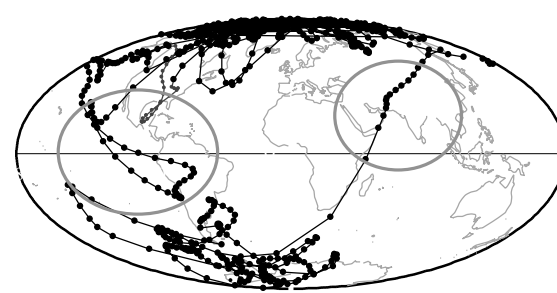
b) 1304B lower Jaramillo



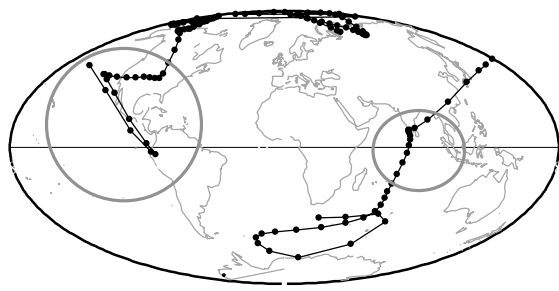
c) 1305A upper Jaramillo



e) 1306D upper Jaramillo



d) 1304B upper Jaramillo



f) 983B upper Jaramillo

