A PALEOCENE PALEOMAGNETIC POLE FROM THE GRINGO GULCH VOLCANICS, SANTA CRUZ COUNTY, ARIZONA

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A Paleocene paleomagnetic pole from the Gringo Gulch Volcanics, Santa Cruz County, Arizona

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Abstract:

Paleomagnetic data from 25 sites (5 samples per site) in andesite flows of the Gringo Gulch Volcanics in Santa Cruz County, Arizona, were analyzed to determine a lower Paleocene paleomagnetic pole. Alternating-field demagnetization to 500 oe peak field was sufficient to erase secondary viscous components. The mean direction of magnetization (inclination = -58.8°, declination = 167.5°) was obtained by averaging the site mean directions of the 25 sites, which are all reversed. The resultant lower Paleocene pole position is at lat. 77.0°N, lon. 201.0°E (dp = 1.2°, dm = 1.7°).

The Cretaceous pole position for North America is quite well determined at lat 64°N, lon 187°E, with A95 of 6° (McElhinney, 1973). The youngest rocks giving this pole position have ages greater than 80 Ma. Three reliable Eocene pole positions are all near the present rotation axis (Løvlie and Opdyke, 1974; Shive and Pruss, 1977; Shive and others, 1977). Clearly, a large amount of apparent polar wander must have occurred during latest Cretaceous and Paleocene time. Prior to this study the only Paleocene pole position based on more than five sites was that given by Butler and Taylor (1978) at lat 75.9°N, lon 147.7°E (dp = 2.7°, dm = 4.1°). However, they speculated that because this pole was derived from a study of sedimentary rocks (of the Nacimiento Formation), the data may be subject to a significant inclination error. Thus it is essential that Paleocene volcanic rocks be studied in order to more confidently determine the details of the apparent polar wander path for this time interval. In turn, the desired data could shed some light on whether the initiation of this episode of rapid apparent polar wander is coincident with the onset of the Laramide orogeny at about 80 Ma. This paper presents results of a paleomagnetic study of lower Paleocene volcanic rocks from southeastern Arizona.

The Gringo Gulch Volcanics (lat 31.53°N, 249.21°E) are largely a sequence of rhyolitic to dacitic tuffs, with some andesitic flows. The total stratigraphic thickness probably exceeds 1600 feet (Drewes, 1972). Our study was restricted to the flat-lying andesite flows in the upper portion of the sequence.

The Gringo Gulch Volcanics unconformably overlie a diorite whose youngest phase has been dated as 65 Ma. Also, the volcanics are believed to be older than several nearby hornblende dacite plugs which have K-Ar ages of 56.4 - 61.5 Ma (all K-Ar ages have been recalculated using revised decay constants given by Steiger and Jäger, 1977). On the basis of these geologic relationships, the Gringo Gulch Volcanics are dated as being between about 60 and 65 Ma (Drewes, 1972). This age seems especially reasonable when considering that the Gringo Gulch Pluton, which the volcanics are believed to be genetically related to and only slightly older than, has a K-Ar age of 61.5 Ma (Drewes, 1976).

Four to six oriented samples were collected from twenty-six flows using standard coring techniques. Alternating-field (AF) demagnetizations were performed using a Schonstedt GSD-1 demagnetizer while remanence measurements were done using a ScT-102 cryogenic magnetometer. Stepwise AF demagnetizations to peak fields of 1,000 oe were carried out for selected samples, including most of those whose directions of natural remanent magnetization (NRM) differed greatly from the average. Most samples did not contain significant secondary components. When present, secondary components appeared to be simply viscous components which were almost always successfully removed by AF demagnetization to peak fields of 500 oe. Details of the AF demagnetization and other rock-magnetic properties will be published in a forthcoming paper.

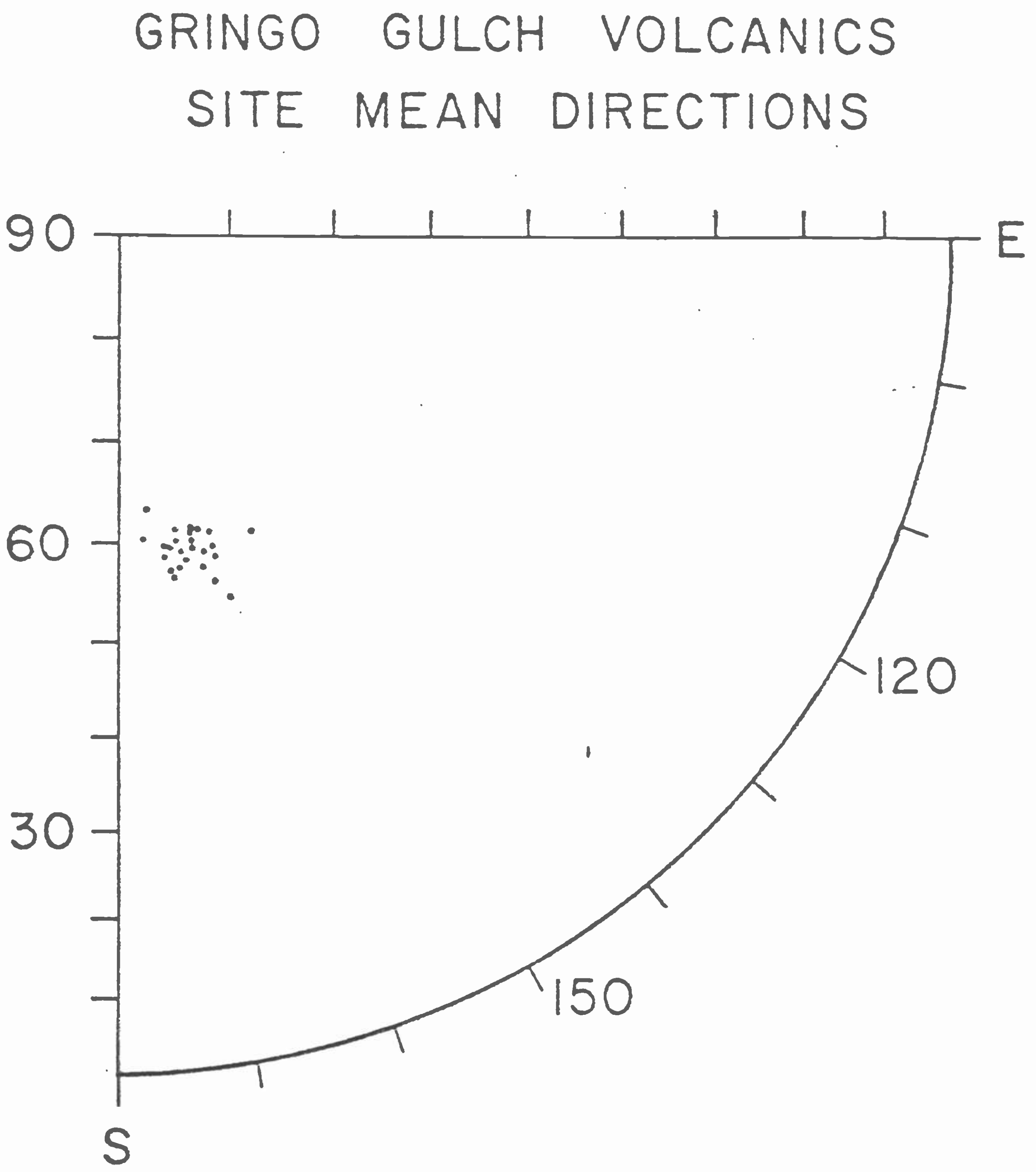
Thermal demagnetizations were also carried out on selected samples. On the average, 28% of the NRM had blocking temperatures below 580°C, while the remaining NRM had higher blocking temperatures. In all cases, the components of NRM with blocking temperatures greater than 580°C were parallel to the lower blocking temperature components. These data suggest that both magnetite (or titanomagnetite) and hematite are present as carriers of the NRM.

The fact that secondary viscous components were successfully removed by AF demagnetization to 500 oe peak field indicates that the secondary components are probably carried by low coercivity multidomain magnetite (or titanomagnetite).

On the basis of the above results on pilot samples, all samples were AF demagnetized at peak fields of both 400 and 600 oe. For most sites, the NRM was found to be very stable and intensities of NRM before and after AF demagnetization average about $3x10^{-4}$ gauss. For a given site, the demagnetization treatment yielding the highest k value was chosen as the appropriate cleaning level for that site. In general, no significant motion of the site mean NRM direction was observed between the two demagnetization treatments. Data from twenty-five of the twenty-six sites, which are all of reversed polarity, were used in the pole position analysis, while data from the remaining site were rejected. The rejected site is characterized by anomalously high NRM intensities, large viscous components which were not successfully removed, and poorly determined mean directions. It is likely that this site was lightning-struck, as it occupies a promontory. A summary of the final site mean results is given in Table 1. Figure 1 is an equal area stereographic plot of the site mean directions.

Most of the site mean directions are statistically different from most of the others, and display a scatter that can be largely attributed to secular variation of the earth's magnetic field. Also, we observed what appeared to be ancient soil profiles developed between several of the flows. This observation suggests that significant time breaks occurred during the extrusion of these flows. We feel, therefore, that the data set has recorded the geomagnetic

Figure 1 - Equal-area stereographic plot of site mean directions. All directions shown are in the upper hemisphere.


GRINGO GULCH VOLCANICS
SITE MEAN DIRECTIONS
90
60
30
E
S
120
150

field over sufficient time to assert that the overall mean direction is an accurate recording of the lower Paleocene axial geocentric dipole field at this location.

The overall mean direction, calculated by treating each site mean direction as a unit vector, is $I_m = -58.8^\circ$, $D_m = 167.5^\circ$. The equivalent normal polarity direction is $I_m = 58.8^\circ$, $D_m = 347.5^\circ$, yielding a paleomagnetic pole at $\lambda_p = 77.0^\circ N$, $\phi_p = 201.0^\circ E$. Statistical parameters are summarized in Table 2 and the pole position is illustrated in Figure 2.

Comparison of this pole position from the Gringo Gulch Volcanics with available data from the Cretaceous and lower Tertiary of North America has several interesting implications. As shown in Figure 2, the Gringo Gulch pole is significantly removed from the pole obtained by Butler and Taylor (1978) from comparable age sedimentary rocks of the Nacimiento Formation. However, Butler and Taylor (1978) speculated that the average direction obtained from the Nacimiento could be subject to an inclination error. If present, the inclination error would yield a mean inclination which is too shallow, and correspondingly the calculated pole position would be displaced too far along a great circle away from the observation locality. Indeed, the Nacimiento pole can be largely reconciled with the Gringo Gulch pole by moving the Nacimiento pole about 12° along a great circle towards the collection locality in the San Juan Basin, New Mexico. This observation suggests that the mean direction from the Nacimiento Formation is subject to an inclination error and that the Gringo Gulch pole is a better record of the lower Paleocene pole position. The Gringo Gulch pole is also in rather nice accord with the Paleocene poles from Montana as reported in the accompanying paper by Jacobson et al (this issue).

Figure 2 - Lower Paleocene pole position derived from the Gringo Gulch Volcanics. Also shown is the pole derived from the Nacimiento Formation. Dashed line is a great circle path from the Nacimiento pole to the collecting site in the San Juan Basin. Ovals around poles are the 95% confidence ovals.

TABLE 1 - Summary of final site mean results. H_{AF} is the peak alternating-field used, I is inclination, D is declination, and J is intensity (in units of 10^{-4} gauss), while k and α_{95} are standard statistical parameters (Fisher, 1953).

Site #	H_{AF} (oe)	I (o)	D (o)	J	# Samples Collected	# Samples Used	k	α_{95} (o)
10	400	-58.8	169.3	3.3	4	4	2145	2.0
11	600	-60.5	175.7	2.6	5	5	1723	1.8
12	600	-57.4	169.5	7.6	5	5	563	3.2
13	400	-55.3	164.1	2.9	6	6	3323	1.2
21	600	-58.4	162.9	2.2	5	5	1380	2.1
22	600	-60.6	169.5	3.5	5	5	1164	2.2
23	400	-56.5	165.9	2.4	6	6	325	3.2
24	400	-56.2	170.7	2.2	5	5	626	3.1
25	600	-58.1	168.7	3.7	5	5	848	2.6
26	600	-53.1	162.7	1.4	5	4	60	11.9
27	600	-58.3	164.5	5.1	6	6	213	4.6
28	400	-61.0	165.8	6.9	5	5	1141	2.3
29	600	-60.6	165.2	6.9	5	5	8570	0.8
30	600	-58.7	172.2	3.4	5	5	1194	2.2
31	400	-59.5	172.2	4.5	5	5	567	3.2
32	600	-60.4	167.1	5.4	5	5	2570	1.5
33	600	-59.8	169.4	8.0	5	5	1518	2.0
34	600	-59.5	171.2	3.4	6	5	2160	1.6
35	600	-58.7	155.8	8.3	5	5	36	12.9
36	600	-60.0	163.3	0.8	5	5	261	4.7
37	600	-63.7	174.5	2.7	5	5	2051	1.7
38	400	-59.8	166.8	4.6	5	5	2375	1.6
39	600	-59.2	167.4	4.2	5	5	1565	1.9
40	600	-57.2	171.3	1.3	5	5	3898	1.2
41	600	-57.8	162.9	4.7	5	5	1544	1.9

TABLE 2 - Summary of formation mean results. N, R, k, α_{95}, dp and dm are standard paleomagnetic statistical parameters (Fisher, 1953).

Site latitude:	31.5°N
Site longitude:	249.2°E
Mean I =	-58.8°
Mean D =	167.5°
N =	25
R =	24.96
k =	678.2
α_{95} =	1.1°
Pole latitude:	77.0°
Pole longitude:	201.0°E
dp =	1.2°
dm =	1.7°

The above data indicate that the episode of rapid apparent polar wander which occurred in latest Cretaceous to Eocene time had commenced before the early Paleocene. The onset of this episode of apparent polar wander is thus confined to a time coincident with the onset of the Laramide orogeny. The coincidence of orogenic episodes with sharp turns or "hairpins" in the path of apparent polar wander has been suggested by Irving and Park (1972). Initiation of this episode of apparent polar wander is almost certainly a reflection of changes in relative and absolute plate motions at the onset of the Laramide orogeny (Coney, 1978).

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