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Paleomagnetism of Paleogene basalts from the Tien Shan, Kyrgyzstan: rigid Eurasia and dipole geomagnetic field

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Abstract

Several conflicting explanations, invoking persistent non-dipole fields or tectonic motion on various scales, were suggested to account for anomalously low paleomagnetic inclinations in Cenozoic rocks of Central Asia. In order to better understand this problem we undertook a paleomagnetic study of Paleogene basalts from a part of the Tien Shan close to the China–Kyrgyzstan border. Stepwise thermal demagnetization showed that only a single-component remanence of reversed polarity is present in these rocks above 200–260°C. The overall mean direction of this remanence ($D = 194.6°$, $I = -54.0°$, $\alpha_{95} = 3.8°$, $n = 18$ sites) agrees well with the Eurasian reference directions for the Paleogene which is in sharp contrast with most earlier published Cenozoic inclinations from Central Asia which are 20–30° shallower than the expected values. Good agreement of the reference inclinations and those from basalts rules out models which invoke non-dipole fields and/or large-scale tectonic motions for explanation of the Cenozoic inclination anomaly. Instead, a mechanism related to natural remanent magnetization acquisition in redbeds is strongly indicated. The above conclusion also implies that the differences between the reference data and measured inclinations in Cretaceous redbeds from Central Asia are also of non-tectonic origin and a revision of our views on evolution of this region is required.

Keywords: paleomagnetism; Paleogene; Kyrgyzstan; magnetic inclination

1. Introduction

The validity of the paleomagnetic method as a tool for studying tectonic motions on various scales depends on two basic assumptions: (1) the geomagnetic field averaged over a 10–100 kyr interval is approximated by a geocentric axial dipole; (2) the remanent magnetization of the rocks was acquired parallel to the ambient field. When a new paleomagnetic result, especially from a tectonically active area, is compared with the reference data, both assumptions are often tacitly accepted, and a difference between the observed and reference directions is taken as an indication of tectonic motion. At the same time, a limited validity of the above assumptions has been demonstrated. For instance, a noticeable deviation from the dipole field has recently been inferred for the last 300 Ma ([1], and references therein).

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Still more numerous are examples when a remanence deviates from the ambient field, the most common case being inclination error in sediments. Hence possible deviations from the above two assumptions and tectonic motions should be jointly considered for a correct interpretation.

An outstanding example of a regional disagreement between the observed and predicted Cenozoic paleomagnetic directions is found in Central Eurasia and generally coincides with the Alpine belt [2]; the largest disparity of 20–30° is observed in Central Asia [3,4]. For the latter region, this Cenozoic inclination anomaly (CIA) was accounted for in the three different ways:

1. tectonic motions either within, or close to, the mobile belts or invoking deformation of the western half of Eurasia [4];
2. non-dipole components of the geomagnetic field [3,5];
3. distortion of the remanence during acquisition and subsequent diagenesis [6].

It is worth noting that 1 and 2 are preferred in most published papers. However, shallowed inclinations from sedimentary rocks, mostly redbeds (for review, [4,3]), cannot be ruled out.

Volcanic rocks are known to be faithful recorders of the ambient field, and paleomagnetic data on them can be used as an *experimentum crusis* with respect to the third option. The preference of sedimentary rocks for paleomagnetic studies in Central Asia stems from the fact that volcanics are nearly absent everywhere. Tertiary basalt flows and minor intrusions, however, have been reported from several places in the Tien Shan mountains [7,8]. Unfortunately, only a single lava flow or an intrusion can be found at most localities, except for a limited mountainous area close to the China–Kyrgyzstan border. In this paper, we present paleomagnetic results on basalts from this area and discuss their tectonic and geophysical implications.

2. Geological setting and sampling

The Tien Shan fold belt (Fig. 1), stretching almost due E–W for about 2500 km in Central Asia, comprises multiply deformed Paleozoic complexes. Latest Permian–Triassic(?) deformation was followed by general uplift and erosion. In the central Tien Shan, the Paleozoic basement is locally overlain with major angular unconformity by Lower–Middle Jurassic terrigenous coal-bearing sediments which accumulated in small basins; the gap in sedimentation, however, lasted well into the Cenozoic over most of the region. Mostly terrigenous Cenozoic sediments unconformably cover the Paleozoic basement or rest with stratigraphic and erosional unconformity on Jurassic rocks in numerous intermountain basins (e.g., [10,11]). Geological evidence and fission track data [12] indicate that the formation of ranges and basins started in the early Miocene, and main folding was in the late Pliocene–early Pleistocene [10].

The basal member of the Cenozoic section in the Central Tien Shan is the Kokturpak Formation which is commonly a few tens of meters thick, locally up to 350 m. This formation comprises brown-red mudstones, poorly sorted carbonaceous sandstones, marls, and limestones which accumulated in ephemeral salt lakes and lagoons in an arid climate [13]. Also characteristic for the basal part of the Kokturpak Fm. are lava units, mainly olivine basalt flows [7,8]. A single flow, rarely two, 1–40 m thick is present at most exposures, the only exception being the Tuyon basin close to the China–Kyrgyzstan border. In China, the total thickness of the basalt bodies is about 300 m [8], while the volcanics are about 80 m

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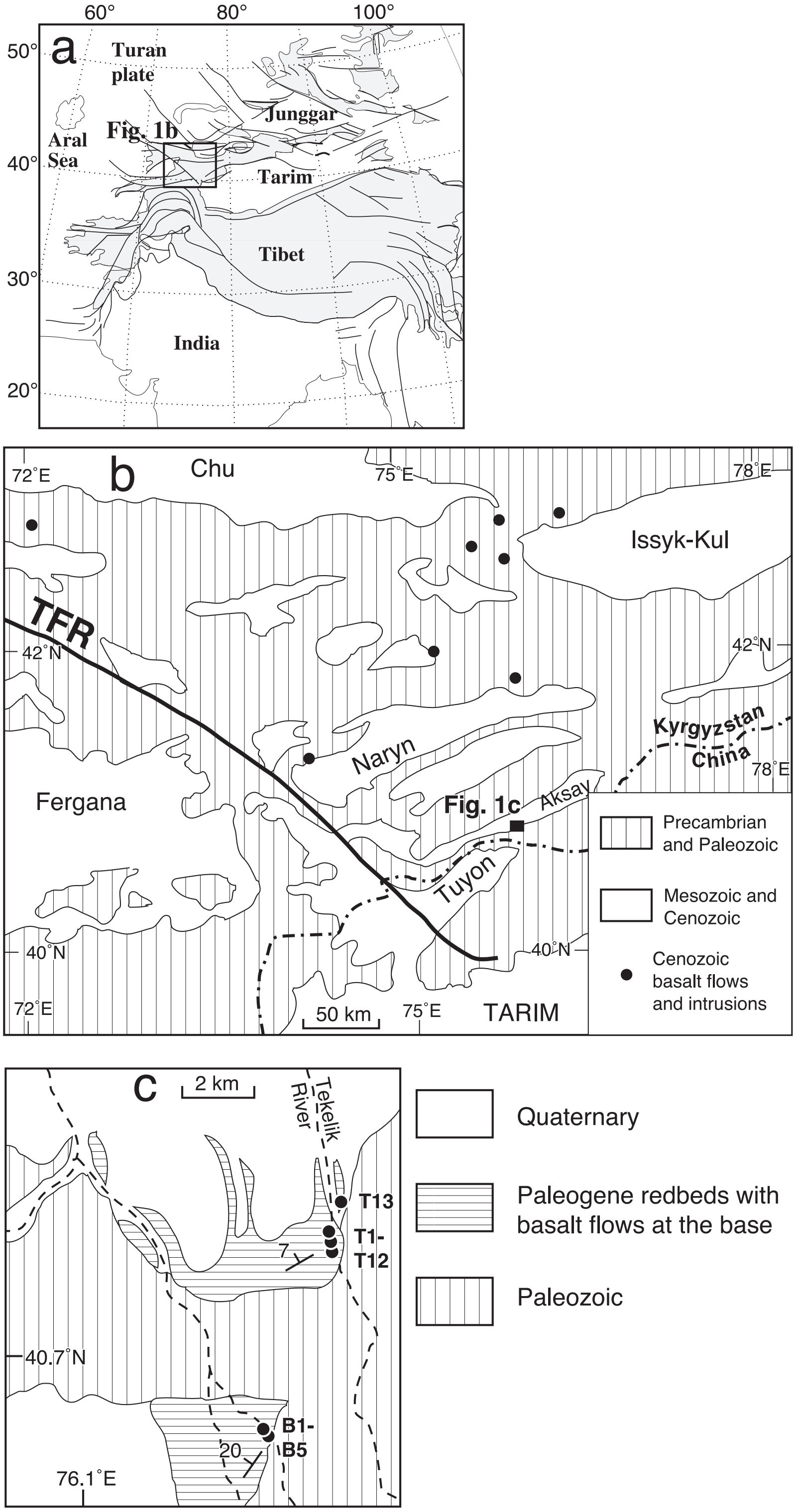
Fig. 1. (a) Location map showing areas with elevation greater than 2 km (shaded) and major faults and sutures (thick solid lines) (simplified after Cobbold and Davy [9]). (b) Distribution of Paleozoic and Mesozoic–Cenozoic rocks (major basins are labeled) in the Tien Shan and the occurrences of volcanic rocks (simplified after Sobel and Arnaud [8]). (c) Schematic geological map of the study area and location of the sampling sites (solid circles).


a
60°
80°
100°
50°
40°
30°
20°
Turan plate
Junggar
Fig. 1b
Aral Sea
Tarim
Tibet
India
b
Chu
72˚E
75˚E
78˚E
Issyk-Kul
TFR
42˚N
42˚N
Kyrgyzstan
China
78˚E
Naryn
Fergana
Fig. 1c
Aksay
Tuyon
40˚N
40˚N
72˚E
50 km
75˚E
TARIM
Precambrian and Paleozoic
Mesozoic and Cenozoic
Cenozoic basalt flows and intrusions
c
2 km
Tekelik River
T13
T1-T12
7
40.7˚N
B1-B5
20
76.1˚E
Quaternary
Paleogene redbeds with basalt flows at the base
Paleozoic

thick in the northwestern part of the basin in Kyrgyzstan (Fig. 1b,c).

A commonly accepted Eocene or Eocene–early Oligocene age of the Kokturpak Fm. is based on scarce mammal remnants (tapiroids) from the Issyk-Kul basin [14] and palynological data [13]. The Kokturpak Fm. is conformably covered by Oligocene–Miocene sediments [11]. Rather dispersed K–Ar ages on volcanics from different exposures in Kyrgyzstan also point, on average, to an early Eocene age ca. 54 Ma [7]. However, pollens from the basal part of the formation may be of late Cretaceous age [13], and pre-Cenozoic Ar–Ar ages have also been reported on some volcanics from the Tuyon basin [8]. Note that the basalt is always present at the very base of the Kokturpak Fm., often directly overlying Paleozoic rocks, and the upper sedimentary part of this formation is very similar all over the Kyrgyz Tien Shan. These facts speak in favor of a close synchronicity of all volcanics in the Tien Shan, and the significance of disparate radiometric ages remains somewhat unclear [8].

The Kokturpak basalts outcrop in a limited area on the northern slope of the Kokshaal Range (Fig. 1b,c). The best exposure is in the canyon of the Tekelik River (loc. T, Fig. 1c) where a basalt pile about 80 m thick is recognized [15]. Less complete basalt exposures are also found to the southwest of the Tekelik locality (loc. B, Fig. 1c). The basalt directly overlies strongly deformed Paleozoic rocks and gently dips to the northwest. In the Tekelik canyon, three weathered horizons were found in the lava section; this and the variation in composition of the rocks made it possible to recognize five flows each 6–40 m thick [15]. At locality B, the number of separate flows is difficult to evaluate because of the discontinuous exposure. However, a flow of brown basalt less than 2 m thick is found among prevailing dark gray rocks; this thin flow has no differences from the other rocks except its color. Moreover, this clearly recognizable unit is not found at the fully exposed Tekelik section.

This observation made us suspect that different sequences are exposed at the two localities, and the total number of flows in the area can be greater than previously thought. In accord with this notion, we sampled the exposures uniformly through the visible thickness and treated each five to seven successive samples as sites. Sixty-eight samples divided into 12 sites were taken from the cliffs of the Tekelik canyon (locality T). Site T13 (seven samples) was sampled at the foot of a high terrace of the same river about 500 m away from the main exposure. Finally, 26 samples were taken from five separate exposures (sites) at the southwestern locality (locality B, Fig. 1c). In total, 101 samples oriented with the aid of a magnetic compass were taken as hand blocks from 18 sites. Bedding attitude and columnar joint measurements were averaged over each locality, and these means were used for tilt correction. The mean azimuths of dip/dip angles are 330/7 and 305/20 for localities T and B, respectively (Fig. 1c).

3. Treatment

The hand samples were cut into cubic specimens with a diamond saw, and the collection was treated in the Paleomagnetic Laboratory in Moscow. The collection was thermally demagnetized in 10–12 steps in an oven with an internal residual field of about 10 nT. All measurements of natural remanent magnetization (NRM) were made on a JR-4 spinner inside a set of large Helmholtz coils which reduced the ambient geomagnetic field by a factor of ~100. Demagnetization results were plotted on orthogonal vector diagrams [16], and linear trajectories were used to determine directions of magnetic components by a least squares fit [17]. Paleomagnetic software for IBM PC by Randy Enkin and Stanislav Shipunov and for Macintosh by Jean-Pascal Cogné was used for the data analysis.

4. Results

NRM intensities of the basalt samples vary from 1 to more than 10 A/m and show no correlation with sample position in the sections. The collection falls into two nearly equal groups with different demagnetization characteristics.

The samples of the first group display a steady decrease of NRM intensity and nearly noiseless decay to the origin on the orthogonal plots (Fig. 2a–c). Characteristic for the second group is a sharp drop of NRM intensity between 200°C and 300°C which is followed by a slower decay at higher temperatures (Fig. 2d,e). Despite noisier orthogonal plots in the second group, the mean magnetization directions of the two groups are nearly identical. Hence we conclude that the same characteristic component, ChRM, is present in all basalt samples. It is worth noting that no secondary component is detected above 200°C in most samples apart from a few more weathered ones from site T13 (Fig. 2f). Irrespective of demagnetization behavior, most samples are demagnetized by 560–600°, indicating magnetite as the main carrier.

Within-site grouping of ChRM vectors is high, and site-mean directions are accurately defined

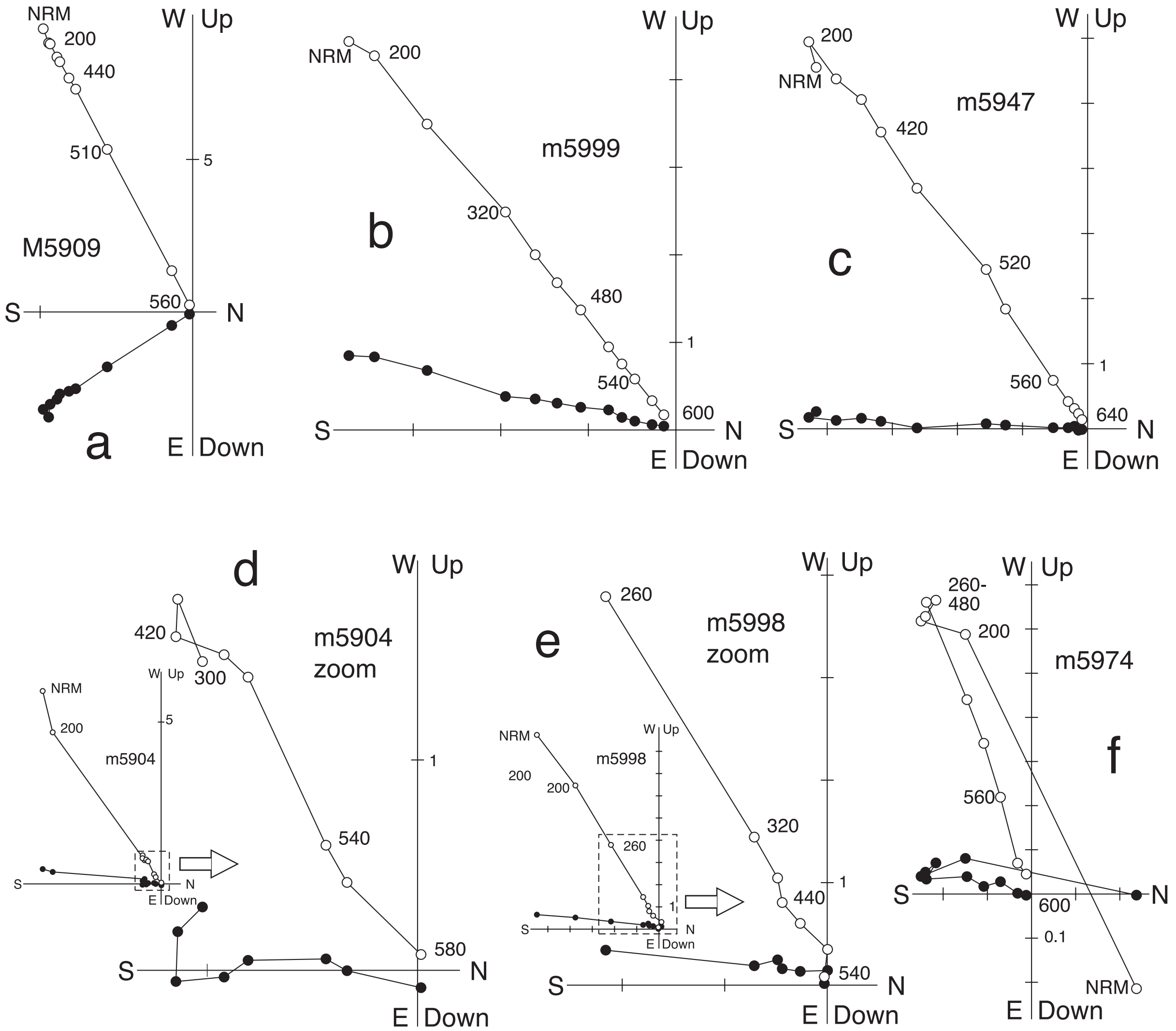


Fig. 2. Representative thermal demagnetization plots of basalt samples in stratigraphic coordinates. Filled and open dots represent vector endpoints projected onto the horizontal and vertical plane, respectively. Temperature steps are in °C. Magnetization intensities are in A/m. For clarity, NRM points are omitted from some plots.

(Table 1). The only exception is site T1 from the lowermost part of the Tekelik section, where three samples close to the contact with Paleozoic rocks yielded deviating directions, while the mean for the next three samples is in agreement with other data (Table 1). It is tempting to connect the anomalous directions with motion of a basalt block during the flow emplacement and regard the anomaly as an argument against later remagnetization of the basalts; this assumption, however, cannot be further substantiated. We decided to reject three anomalous samples from calculation of the overall mean.

Site means are slightly better clustered after tilt correction than in situ, but this improvement in data grouping is statistically insignificant (Table 1; Fig. 3), while the fold test of McFadden and Jones [19] is definitely positive (Table 1), despite the minor difference in bedding attitudes. The significance of the fold test is limited because the deformation in the Tien Shan is of Pliocene to Quaternary age [10]; the same, however, is true for all Cretaceous and Cenozoic data north of Tibet. The primary origin of the remanence is further supported by the presence of the single well-defined component, its reversed polarity, and the absence of overprints, with the only exception of weathered samples from site T13. Note also that overlying sedimentary rocks above the basalt pile are weakly indurated and show no signs of metamorphism. The total thickness of Cenozoic sediments in the Tuyon basin is 1000–2000 m, and thermoviscous remagnetization of basalt because of deep burial looks unlikely. Basaltic lavas have low viscosity and, generally, do not accumulate on surfaces inclined by more than 5°; hence an unaccounted-for primary tilt can hardly introduce a large error into the data. Finally, the low scatter of remanence directions at both within- and between-site levels indicates that

Table 1
Site-mean paleomagnetic results for ChRM in Tertiary basalts

Site	*n*	In situ				Tilt-corrected			
		D (°)	*I* (°)	*k*	α_{95} (°)	*D* (°)	*I* (°)	*k*	α_{95} (°)
T1	6/3	214.7	−63.1			204.3	−59.1	70	14.8
T2	5/5	172.1	−66.2			168.5	−59.4	65	9.6
T3	5/5	211.8	−67.0			200.2	−62.5	399	3.8
T4	6/5	204.1	−57.9			196.8	−53.0	369	4.0
T5	6/6	204.3	−61.5			196.0	−56.6	47	9.8
T6	6/6	186.8	−58.1			181.9	−52.0	22	14.5
T7	6/6	215.4	−55.4			207.5	−51.6	251	4.2
T8	6/6	211.6	−59.4			203.0	−55.1	48	9.7
T9	5/5	201.1	−60.6			193.5	−55.4	505	3.4
T10	5/5	207.7	−55.7			200.6	−51.1	133	6.7
T11	5/5	186.2	−47.2			182.8	−41.1	253	4.8
T12	7/7	186.5	−45.7			183.2	−39.7	74	7.1
T13	7/6	213.7	−67.8			201.4	−63.5	42	10.4
All T	**(13/13)**	**200.5**	**−59.6**			**193.3**	**−54.3**	**69**	**5.0**
B1	5/4	239.2	−55.1			209.1	−56.7	126	6.8
B2	5/5	226.9	−57.5			196.9	−54.6	43	14.1
B3	4/3	221.1	−55.2			194.6	−50.8	469	5.7
B4	6/6	217.3	−50.3			195.5	−45.5	70	8.1
B5	6/6	227.3	−60.5			193.3	−56.7	92	7.0
All B	**(5/5)**	**225.9**	**−56.0**			**197.6**	**−53.0**	**180**	**5.7**
Mean	**(18/18)**	**208.1**	**−59.1**	**56**	**4.6**	**194.6**	**−54.0**	**85**	**3.8**
$F_{(2,32)} = 3.3$		$f = 8.75$				$f = 0.4$			

n, number of samples (sites) studied/used; *D*, declination; *I*, inclination; *k*, precision parameter [18]; α_{95}°, radius of cone of confidence; *F*, 95% critical value of *F* statistics with the number of degrees of freedom in parentheses; *f*, calculated values of the same statistics.

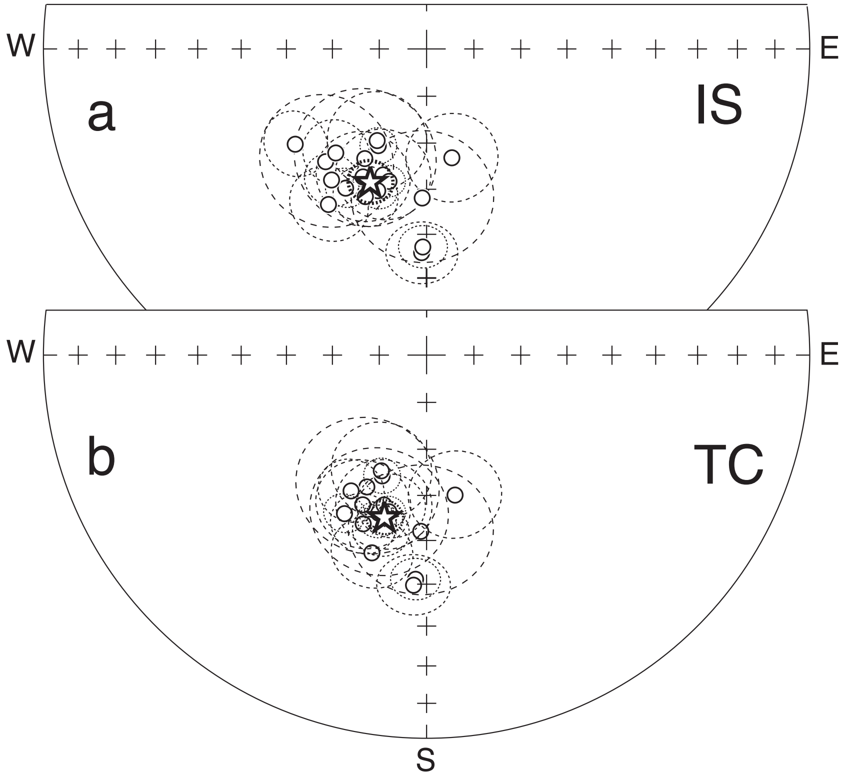


Fig. 3. Equal-area projection of site-mean directions (dots) of the ChRM together with associated confidence circles (thin lines) and overall mean (star) with associated confidence circles (thick dashed line) in situ (a) and after tilt correction (b). Open or solid symbols and dashed/dotted or solid lines are projected onto upper or lower hemispheres, respectively.

the sampling with the aid of a magnetic compass did not insert appreciable errors into the paleomagnetic results. Of course, minor errors are possible, but they are hardly systematic and are adequately averaged.

We are not sure that each site is independent of the geomagnetic field: some sites can be taken from the same flow, and the accuracy of the mean can be overestimated. Even if we assume that the number of independent spot readings is two times less, i.e., $n = 9$, the radius of the confidence circle will increase to about 5°, which is still small. A concentration parameter value of 85 falls within the limits which are expected for a data set where secular variation is adequately averaged out (e.g., [20]). Thus we conclude that the overall mean direction of the ChRM in the Tekelik basalts is an accurate estimate of the paleofield.

Sobel and Arnaud [8] reported the ages of volcanics from the Tuyon basin to range from 46 to 113 Ma; scatter from 21 to 100 Ma was also found in Kyrgyzstan [7]. In particular, three K–Ar ages of the Tekelik basalts range from 50 to 74 Ma [21]. The reversed polarity of all basalt samples from two localities, however, casts doubts on the validity of these three ages as the geomagnetic field changed polarity between 50 and 74 Ma [22], and it is unlikely for volcanics to have been selectively erupted during the reversed chrons. To the same effect speaks the fact that basalt bodies invariably occur at the very base of the Kokturpak Fm. in Kyrgyzstan, and the above sedimentary part of this formation is very similar all over the region. Somewhat tentatively, we ascribed a 50 Ma age to the basalts studied, in accordance with an earlier estimate [7], and allowed for a ± 15 Ma confidence limit to this age.

5. Interpretation

Cenozoic paleomagnetic data were reported from several localities north of Tibet and the Pamirs. These localities are not very far away from our study area (Fig. 4a), and most paleomagnetic directions either show no rotation with respect to the reference paleomeridian, or the rotations are relatively small, usually less than 20° [3,23–27]. Hence all data can be recomputed to our study area (40.7°N, 76.1°E) with negligible recalculation errors [28] and compared with reference directions derived from the master apparent polar wander path in the Eurasian coordinates [29].

Most recalculated Paleogene and early Neogene inclinations in sedimentary rocks are lower by 20–30° than the reference data (Fig. 4b), in accordance with earlier findings [3,4,24]. Note that

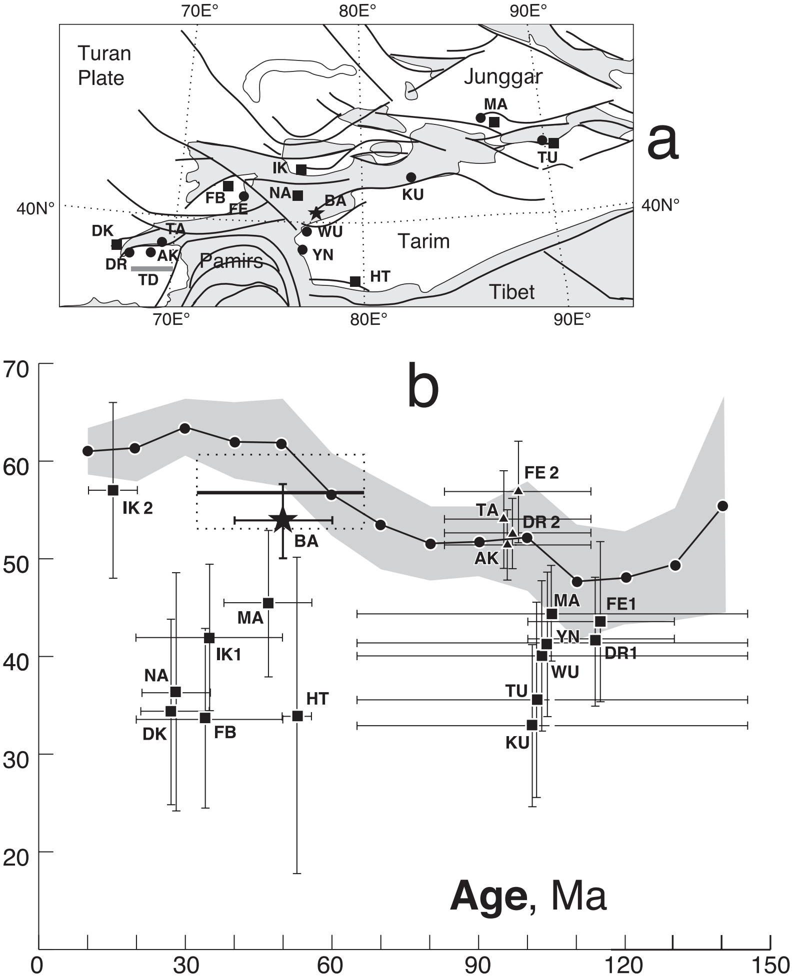


Fig. 4. (a) Distribution of sampling localities of Cretaceous (dots) and Paleogene (squares) rocks in the Tien Shan and adjacent areas. Notation on the map is as for Fig. 1a. Data: AK, DR, TA [37]; DK [3]; FB, YK, NA [24]; FE [38]; HT [27]; KU [32]; MA, TU [26]; WU, YN [33]; BA, this study (star). Shaded rectangle (TD) denotes a profile along which variously rotated Paleogene declinations were found [25]. (b) Plot of predicted and measured inclinations recalculated for the study area (40.5°N, 76.5°E) versus time. The reference data are from the master apparent polar wander path in the Eurasian coordinates [29]. Thick horizontal line and dotted rectangle are Paleogene reference inclination and its confidence limits from Van der Voo [28]. Observed inclinations are labeled as in (a). Indices 1 and 2 denote intermediate- and high-temperature components, respectively, isolated from the same locality. Horizontal bars are age limits for the rocks studied.

the original DK inclination of 30 ± 9° from the Southwest Ghissar Range [3] (Fig. 4a) is in good agreement with the overall mean inclination of 34.6 ± 6.3° from rotated sections in the Tadjik Depression [25], which cannot be directly recalculated to the common point. Thus the number of results with inclinations of about 35° is still larger than that shown in Fig. 4b. Somewhat steeper are the inclinations from the Manas area of the north Chinese Tien Shan [23] and the Issyk-Kul basin [24]. The latter result is a composite based on the data from three localities: a single flow of the Kokturpak basalt (i.e., roughly synchronous with the Tekelik basalts) and Oligocene–Lower Miocene redbeds from two different localities gave similar inclinations, 42 ± 8° on average (nine sites), whereas the mean inclination in Miocene gray sandstones from the third locality (four sites) is much steeper ($I = 57 \pm 9°$) (YK1 and YK2, respectively, Fig. 4b). Apart from the latter result, all other Cenozoic inclinations form a dense cluster well below the reference data (Fig. 4b).

Several lines of evidence have been cited to justify that the Cenozoic rocks studied are faithful recorders of the geomagnetic field, the first one being the regional consistency of the data. However, this reasoning is vulnerable as nearly all Cenozoic paleomagnetic data are from redbeds, and the regional consistency may simply indicate that the same mechanism is responsible for NRM acquisition. The second line of evidence is that redbed inclinations are in general agreement with the data on basalts from the Issyk-Kul basin which are somewhat shallower than the reference values indeed ($I = 44 \pm 14°$) [24]. However, a single basalt flow less than 2 m thick was studied, and thus the result is just a spot reading of the ambient field.

The absence of a noticeable anisotropy of magnetic susceptibility (AMS) in redbeds was cited against inclination shallowing too; for instance, Chauvin et al. [3] found AMS ranging from 2 to 6% in Oligocene–Lower Miocene redbeds in the Southwest Ghissar Range (loc. DK, Fig. 4a). Weak AMS is not too convincing as both isotropic red pigment and strongly anisotropic specularite grains are common in redbeds and the characteristic component may reside in a more anisotropic fraction, while weak AMS is mainly due to the isotropic pigment. A minor amount of magnetite is also common in redbeds as it was found in different parts of Central Asia (e.g., [3]). Magnetite grains do not contribute to NRM in redbeds but may greatly influence their AMS.

Thus there is no compelling evidence that Tertiary redbeds of Central Asia faithfully record the ambient field, and some researchers have already suspected widespread inclination shallowing in these rocks [6]. Moreover, there are several studies where inclination shallowing in redbeds from other regions has been convincingly demonstrated [30,31].

The difference F of 7.9 ± 4.8° between the mean inclination in the Tekelik volcanics and the 50 Ma reference direction is small but statistically significant; similar F values are observed with respect to younger reference data too (Fig. 4b). In contrast, parameter F is insignificant for the 60 Ma reference values, and is equal to zero for 70 Ma ones. Also, the Tekelik inclination differs by 2.8 ± 4.3° from the reference inclination (Fig. 4b) recalculated from the mean Paleogene (37–66 Ma) pole based only on the Eurasian data [28]. Taking into account the above-discussed ambiguities in the age of the basalt units in the Tien Shan, we conclude that our result agrees with the reference data within the error limits of the available data set.

Also important is that the mean inclination in basalts is much steeper than those in sedimentary rocks of Cenozoic age (Fig. 4b). This finding strongly indicates that the Tertiary inclinations in redbeds are shallowed. Hence the CIA is accounted for by the NRM acquisition process, and not by non-dipole components in the Cenozoic geomagnetic field or large-scale deformation of the Eurasian plate.

Cretaceous inclinations north of Tibet [23,32–34] are also shallower than the reference data (Fig. 4b). This was interpreted as the result of a convergence of Central Asia units with North Eurasia; in particular, a convergence of ca. 1000 km north of Tarim was inferred [34]. The attempts to directly connect shallowed Cretaceous inclinations with tectonic motions, however, raise several objections.

1. All oceans had been closed in Central Asia well before the Cretaceous, and subsequent displacements had to take place within the already consolidated crust and hence inevitably created large deformations. There are, however, no large angular unconformities within the Cretaceous–Paleogene sections in the Tarim basin, Tien Shan and further to the north, and the main deformation here is of late Cenozoic age. Hence the assumed large-scale convergence had to take place after the late Miocene and requires velocities exceeding 20 cm/yr, which appears to be too great for motions within continuous continental lithosphere.
2. Paleozoic zones and sutures can be traced along the entire Tien Shan belt, from the Turan plate in the west to the eastern part of this belt north of Tarim where shallow Cretaceous inclinations are found [23,32]. An attempt to account for shallow inclinations by recent tectonic motions will disrupt the now continuous Tien Shan belt, which looks very unlikely.
3. Inferred northward motion postdates the emplacement of the basalts, where paleomagnetic data do not indicate a significant poleward displacement.
4. The inclinations of both secondary components of presumably late Cretaceous age and primary components in Lower Cretaceous redbeds from the Fergana Basin, southwest Tien Shan, and the Tadjik depression [35–37] agree with the reference data and indicate no significant poleward motion (Fig. 4b).

The above controversies will evaporate if inclination shallowing is present in Cretaceous data from West China too, and paleomagnetic inclinations cannot be directly used to evaluate the magnitudes of late Cenozoic displacements connected with the India–Eurasia collision. There is no doubt that this collision resulted in major intracontinental deformation in Eurasia, and the challenging question is to accurately evaluate it.

Inclination shallowing with respect to the reference values is different in Cretaceous and Paleogene redbeds (Fig. 4b). We know of no systematic work on lithology and rock magnetism of these redbeds and would abstain from fruitless speculations. But if two redbeds show inclination shallowing of different magnitude, how can one recognize good cases from bad ones, and how bad are the bad cases? These questions were initially addressed at least two decades ago (e.g., [30]) but remain unresolved. It may happen that inclination shallowing in redbeds is more widespread than previously thought and may account for some long-standing enigmas. One of them is an apparently equatorial position of Precambrian glaciations; note, however, that the most reliable paleomagnetic results ([38] and references therein) are on fine-grained redbeds, and no set of paleomagnetic reliability criteria includes the test of inclination shallowing. In fact, a paleolatitude of 15° was found in Upper Permian red siltstones of South Kazakhstan [39], whereas other contemporaneous data indicate paleolatitudes of 30–35° for this region ([40] and references therein). If strong inclination shallowing happened in the Permian and Cenozoic rocks, why could it not take place in the Precambrian ones, at least in some cases?

6. Conclusion

We undertook a paleomagnetic study of Paleogene basalts from a part of the Tien Shan close to the China–Kyrgyzstan border. Stepwise thermal demagnetization showed that the only single-component remanence of reversed polarity is present in these rocks above 200–260°C. The overall mean direction of this remanence ($D = 194.6°$, $I = -54.0°$, $\alpha_{95} = 3.8°$, $n = 18$ sites) is found to agree well with the Eurasian reference data. This result is in sharp contrast with most earlier published Tertiary inclinations from Central Asia which are 20–30° shallower than the expected values. Good agreement of the reference inclinations and those from basalts rules out the models which invoke non-dipole field and/or large-scale tectonic motions to explain the CIA; instead, a mechanism related to NRM acquisition in redbeds is strongly indicated. Indirectly, the above conclusion implies that the differences between the reference data and measured inclinations in Cretaceous redbeds from Central Asia may be of non-tectonic origin too, and a revision of our views on the evolution of this region is required.

We are well aware that one result based on a limited number of lava flows leaves room for doubt, and better defined data are needed. The evident opportunity is the Chinese part of the Tuyon basin with its 300 m thick volcanic sequence with varying bedding attitudes [8]. More difficult is finding Cretaceous volcanic rocks in Central Asia to carry out a similar test: a single lava flow among Lower Cretaceous redbeds in the northeastern Fergana basin is clearly not a good target, and we know of no other places with Cretaceous volcanics north of Tibet and the Pamirs. Another solution is to invent more accurate methods to evaluate inclination shallowing in redbeds.

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