When did hominids first leave Africa?: New high-resolution magnetostratigraphy from the Erk-el-Ahmar Formation, Israel

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ABSTRACT

New paleomagnetic results from the Erk-el-Ahmar Formation, Israel, resolve age ambiguities of one of the oldest hominid sites outside Africa, where ancient Oldowan tools and artifacts were excavated. We identified in the section the upper and lower boundaries of the Olduvai subchron, and we conclude that these sediments were deposited between ca. 1.7 and 2.0 Ma. This result is consistent with the hypothesis that earliest hominid migrations from Africa to Eurasia during the early Paleolithic traversed the Levantine corridor.

Keywords: hominid migrations, Oldowan tools, Olduvai subchron, magnetostratigraphy.

INTRODUCTION

It is now generally accepted that central-east Africa was the springboard for hominid evolution in the latest Miocene or early Pliocene, ca. 4–5 Ma (e.g., Dean and Delson,1995). The timing and pathways of hominid migrations from Africa to Eurasia are not well known and are current topics for research (e.g., Bar-Yosef, 1998). During the past decade there were several new age determinations of ancient "out of Africa" hominid sites: Dmanisi, Republic of Georgia, ca. 1.7 Ma (Gabunia and Vekua, 1995; Gabunia et al., 2000), and Java, Indonesia, 1.66–1.81 Ma (Swisher et al., 1994). These results suggest an earlier hominid presence outside Africa than previously recognized. The Levantine corridor was one of the most accessible routes between central-east Africa and Eurasia during Neogene time (e.g., Bar-Yosef, 1998). Therefore, it is not surprising that some of the most ancient early Paleolithic sites of hominid activity outside Africa are in the Middle East (Fig. 1). The oldest known hominid site in this region is the Erk-el-Ahmar Formation in the central Jordan Valley (Horowitz, 1979; Tchernov, 1999, p. 392), where "core-choppers and flakes, considered as typical Oldowan tools, were uncovered from fluviatile layers."

Early workers considered the Erk-el-Ahmar correlative with the 'Ubeidiya Formation, which represents one of the oldest known industrial cultures of *Homo erectus* outside Africa (Horowitz, 1979; Bar-Yosef, 1998; Tchernov, 1999). The 'Ubeidiya excavations, located ~3 km south of the Sea of Galilee on the west bank of the Jordan River (a few kilometers north of the Erk-el-Ahmar outcrops), have yielded a wealth of archaeological finds, including skull fragments, teeth, and an associated early tool industry (Tobias, 1966; Stekelis et al., 1969). Age limitations based on biostratigraphy together with cultural evidence suggest an age of ca. 1.4 Ma for the 'Ubeidiya Formation (Tchernov, 1987, 1999), consistent only with reverse magnetic polarity that was measured for this formation (Opdyke et al., 1983). There are no mapped contacts between the 'Ubeidiya and Erk-el-Ahmar Formations. The Erk-el-Ahmar contains eight species of molluscs that are either extinct or have retreated from the entire region and are not found in the 'Ubeidiya or younger deposits (Tchernov, 1987). It is now generally recognized from examinations of pollen, molluscs, and charophyte as-

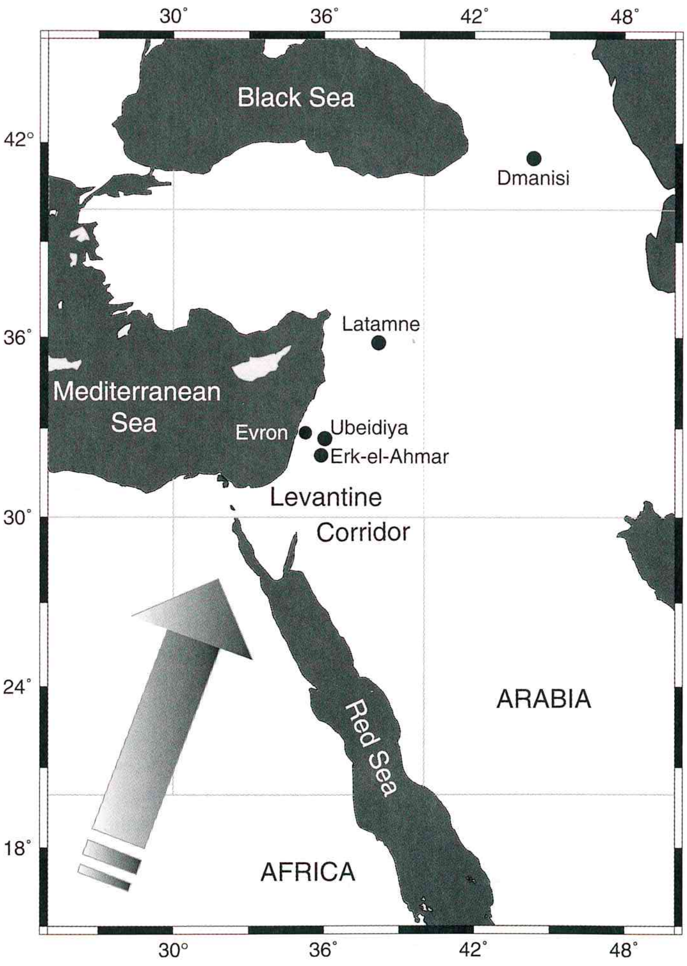

Figure 1. Map of Middle East including parts of northeast Africa and Arabia, showing hominid sites older than 1 Ma (Erk-el-Ahmar, 'Ubeidiya, Dmanisi, Evron, and Latamne from Tchernov, 1999). Arrow indicates general (and subjective) direction of hominid migration(s).

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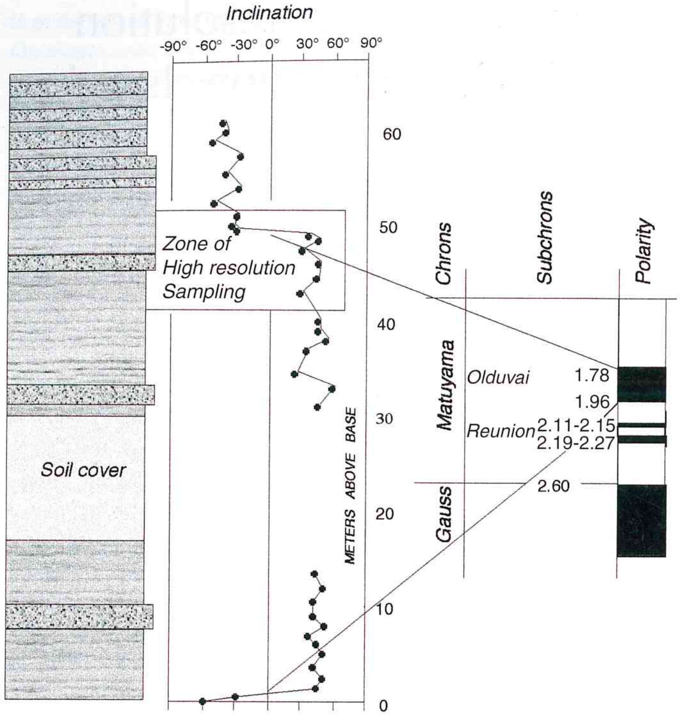


Figure 2. Inclination profile of northern outcrop of Erk-el-Ahmar section (modified from Braun et al., 1991), showing zone of high-resolution sampling and appropriate segment of magnetic polarity time scale. Polarity boundary ages (McDougall et al., 1992) are in millions of years.

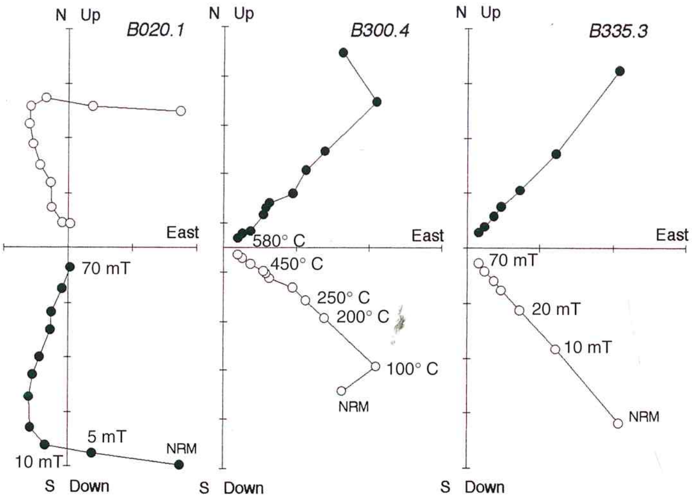


Figure 3. Vector projection diagrams of representative Erk-el-Ahmar specimens during thermal and alternating field demagnetization of normal and reverse specimens. Open symbols denote projection onto vertical plane; closed symbols denote declinations. NRM, natural remanent magnetization.

semblages that the Erk-el-Ahmar predates the ‘Ubeidiya Formation (Horowitz, 1979; Tchernov, 1987, 1999).

BACKGROUND

The study area (Fig. 1), the type locality of the Erk-el-Ahmar Formation, is ~10 km south of the Sea of Galilee along the west bank of the Jordan River. At this site the section thickness is ~70 m (Fig. 2). The Erk-el-Ahmar sediments comprise fine-grained lacustrine and fluviatile strata, mainly brown clays and marls with some intercalations of clayey varves; silts and sands are less common. Some of the layers have very rich freshwater malacological assemblages, as well as fish remains (Tchernov, 1975, 1987). The formation was faulted and tilted by the Dead Sea transform and graben tectonism (Picard and Baida, 1966). At the study area the section dips 10°–20° to the east; the parallel layering of the strata is consistent, and there are no significant postdepositional disturbances. The section is truncated by an angular unconformity and is overlain in places by the horizontal Lisan Formation of Wurm age (Begin et al., 1980) and in one locality by the Yarmuk Basalt, which has a K-Ar age of 0.6 Ma (Heimann, 1990). The base of the Erk-el-Ahmar overlies the Cover Basalt; these flows have K-Ar ages of 5.1–3.3 Ma (Heimann, 1990). High-resolution magnetic stratigraphy in association with biozonation offers an excellent opportunity to improve the accuracy and precision of the age of the Erk-el-Ahmar Formation to further clarify the chronology of hominid migration(s) between Africa and Eurasia.

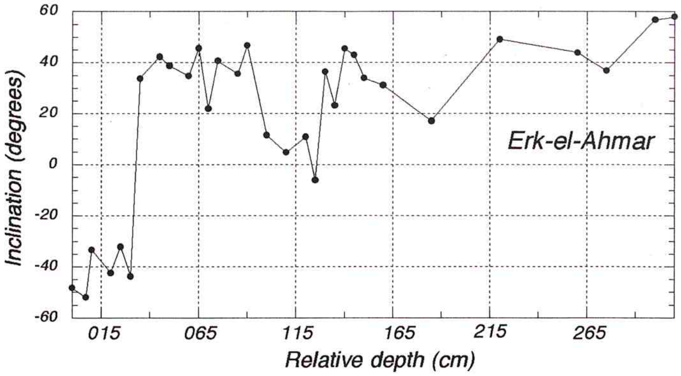
Previous paleomagnetic studies (Braun et al., 1991; Verosub and Tchernov, 1991) showed that the Erk-el-Ahmar Formation is represented by both normal and reverse polarity. Braun et al. (1991) conducted broad-brush magnetostratigraphy at the type Erk-el-Ahmar locality, but their results permit several interpretations, which lead to age ambiguities of as much as 0.4 m.y. A primary goal of our study has been to resolve this ambiguity to provide a more accurate chronology of the Erk-el-Ahmar.

METHODS

The soft, friable sediments were sampled by carving cubic pedestals and placing over them plastic sample boxes, which were oriented before the specimens were removed from the outcrop. The sample boxes were shown to contribute negligible magnetic noise. The natural remanence of the specimens was stepwise demagnetized in alternating fields (AF) to 60 or 80 mT in increments of 5 or 10 mT. Representative samples were thermally demagnetized. All the measured specimens retained a characteristic direction, and the results from the thermally demagnetized specimens were consistent with those treated with AF. Typical demagnetization patterns are shown in Figure 3.

RESULTS

After confirming the reversal boundaries previously identified by Braun et al. (1991), we conducted comprehensive sampling and analysis to bracket the reversal near 50 m (Fig. 2). The 5.2-m-thick segment includes data from 42 horizons. Each point in Figure 4 is a horizon average, typically from three independently oriented specimens. The results for each specimen represent characteristic directions obtained by progressive AF demagnetization, and corrected for bedding attitudes. The inclinations of the upper 3.1 m (31 horizons) are shown in Figure 4. The lower 2.1 m (11 horizons not shown in Fig. 4) have uniform normal polarity. The data show several interesting features: (1) The lower 3 m (15 horizons) have normal polarity with average inclination ~48° and declination ~40°. The average inclination is ~6° shallower than expected from the geocentric axial dipole—behavior not uncommon especially for lacustrine sediments (Levi and Banerjee, 1990; Arason and Levi, 1990). (2) The average declination in the stable polarity zones (36 horizons), both normal and reverse, indicates about 35° clockwise rotation of the section since deposition. (3) The polarity reversal occurs in no more than 5 cm, and no transitional directions were observed. (4) In the upper part of the normal polarity zone, ~1 m below the reversal there are four horizons (Fig. 4), representing ~0.3 m of section, the average inclination of which is 8°; the declinations are rotated ~35° counterclockwise relative to the remaining section, i.e., a miniexcursion in the normal polarity interval.



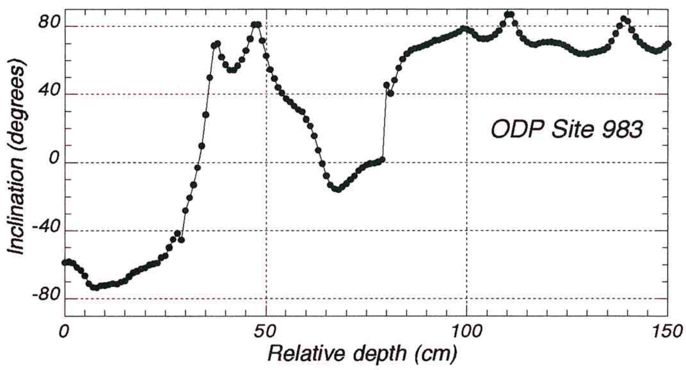


Figure 4. Inclination profiles of upper boundary of Olduvai subchron from Ocean Drilling Program (ODP) Site 983 (Mazaud and Channell, 1999) and Erk-el-Ahmar (this study). Each profile has its own depth scale. Each point of Erk-el-Ahmar profile is horizon average of (typically) three specimens. ODP data represent U-channel measurements taken every 1 cm with pass-through magnetometer.

DISCUSSION

Our interpretation of the magnetic stratigraphy of the Erk-el-Ahmar section correlates the normal zone in the section with the Olduvai subchron from 1.96 to 1.78 Ma (McDougall et al., 1992), nearly identical to the astronomically calibrated time scale (e.g., Lourens et al., 1996). This leads to an average sedimentation rate for the Erk-el-Ahmar section of 0.27 mm/yr (27 cm/k.y.), and the extrapolated age at the top of the outcrop is ca. 1.71 Ma (Fig. 2).

This new interpretation is consistent with the biostratigraphic observations, which indicate that the Erk-el-Ahmar pre-dates the 'Ubeidiya Formation. In addition, recent high-resolution paleomagnetic measurements of North Atlantic Neogene sediments at Ocean Drilling Program Site 983 (Mazaud and Channell, 1999) show that the Olduvai subchron exhibits a zone of shallow inclinations prior to its termination, very similar to the results in the Erk-el-Ahmar sediments (Fig. 4). The similar inclination patterns for these differing sedimentary regimes give us added confidence that the normal zone in the Erk-el-Ahmar section is the Olduvai subchron. According to this interpretation, the excursion near the top of the Olduvai subchron in the Erk-el-Ahmar preceded the polarity reversal by 3–3.5 k.y. and endured for about 1–1.5 k.y. In the North Atlantic sediments, this excursion preceded the Olduvai termination by 2–2.5 k.y., lasting ~1–1.5 k.y. The similar inclination patterns of the Olduvai excursion at such widely separated regions suggest that this fluctuation was caused by low-order harmonics, possibly a dipolar feature, of the main geomagnetic field. If this interpretation is correct, the upper Olduvai excursion should be observed at other high-resolution sections over large regions of the Northern Hemisphere and possibly globally; this will be tested by future studies.

This new magnetostratigraphic interpretation supersedes the results of Braun et al. (1991). The firm identification of the Olduvai subchron as the predominant normal zone in the Erk-el-Ahmar section removes the ambiguity in the former study, where the normal zone was considered as one of the two Reunion subchrons. If we use the McDougall et al. (1992) magnetic polarity time scale, the age of the Erk-el-Ahmar is as much as 0.4 m.y. younger than the age determined in the earlier study. Additional support for the new interpretation comes from the considerably lower sedimentation rates for the Erk-el-Ahmar in this study compared to the rates of Braun et al. (1991): 0.27 mm/yr versus 1.6 or 2.4 mm/yr. These lower average sedimentation rates are more realistic, especially considering the 0.86 mm/yr value for the overlying Lisan Formation (Marco et al., 1998).

While the above interpretation is the most probable and consistent with the existing data, it is not unique. It remains possible that the normal segment that we correlate with the Olduvai represents a different subchron. In particular, the younger of the Reunion subchrons, dated as 2.13 to 2.15 Ma (Baksi and Hoffman, 2000), recorded an excursion similar to the one reported here for the Erk-el-Ahmar. However, this alternative interpretation seems unlikely by the preceding arguments. It would require as much as a 10-fold increase in the average sedimentation rate for the Erk-el-Ahmar section.

The hominid tools excavated from the Erk-el-Ahmar Formation, which include "core choppers and flakes made of flint" (Tchernov, 1999, p. 389) were discovered 1.5 km southwest of our sampling site, and so far it has not been possible to correlate these two locations precisely. Thus, the best estimate for the age of the earliest presence of hominid populations in the Levant is 1.7–2.0 Ma. While this age estimate might change with improvements in the magnetic polarity time scale, the recognition of the Olduvai subchron in this section significantly reduces uncertainties and improves the accuracy of dating the earliest known hominid activity outside Africa. It is worth noting that the most ancient hominid sites at Dmanisi, Java, and Erk-el-Ahmar have very similar ages, which are probably experimentally indistinguishable, suggesting the possibility that this phase of hominid dispersal occurred relatively rapidly.

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REFERENCES CITED

Arason, P., and Levi, S., 1990, Models of inclination shallowing during sediment compaction: Journal of Geophysical Research, v. 95, p. 4481–4499.

Baksi, A.K., and Hoffman, K.A., 2000, On the age and morphology of the Reunion event: Geophysical Research Letters, v. 27, p. 2997–3000.

Bar-Yosef, O., 1998, Early colonizations and cultural continuities in the Lower Palaeolithic of western Asia, *in* Petraglia, M.D., and Korisettar, R., eds., Early human behaviour in global context: The rise and diversity of the Lower Palaeolithic record: London and New York, Routledge, p. 221–279.

Begin, Z.B., Nathan, Y., and Ehrlich, A., 1980, Stratigraphy and facies distribution in the Lisan Formation: New evidence from the area south of the Dead Sea, Israel: Israel Journal of Earth Sciences, v. 29, p. 182–189.

Braun, D., Ron, H., and Marco, S., 1991, Magnetostratigraphy of the hominid tool bearing Erk el Ahmar formation in the northern Dead Sea rift: Israel Journal of Earth Sciences, v. 40, p. 191–197.

Dean, D., and Delson, E., 1995, *Homo* at the gates of Europe: Nature, v. 373, p. 472–473.

Gabunia, L., and Vekua, A., 1995, A Plio-Pleistocene hominid from Dmanisi, East Georgia, Caucasus: Nature, v. 373, p. 509–512.

Gabunia, L., Vekua, A., Lordkipanidze, D., Swisher, C.C., III, Ferring, R., Justus, A., Nioradze, M., Tvalchrelidze, M., Anton, S.C., Bosinski, G., Joris, O., de Lumley, M.-A., Majsuradze, G., and Mouskhelishvili, A., 2000, Earliest Pleistocene hominid cranial remains from Dmanisi, Republic of Georgia: Taxonomy, geological setting, and age: Science, v. 288, p. 1019–1025.

Heimann, A., 1990, The development of the Dead Sea rift and its margins in northern Israel during the Pliocene and the Pleistocene: Golan Research Institute and Geological Survey of Israel Report GSI/28/90, 90 p. (in Hebrew with English abstract).

Horowitz, A., 1979, The Quaternary of Israel: New York, Academic Press, 394 p.

Levi, S., and Banerjee, S., 1990, On the origin of inclination shallowing in redeposited sediments: Journal of Geophysical Research, v. 95, p. 4383–4389.

Lourens, L.J., Antonarakou, A., Hilgen, F.J., Van Hoof, A.A.M., Vergnaud-Grazzini, C., and Zachariasse, W.J., 1996, Evaluation of the Plio-Pleistocene astronomical timescale: Paleoceanography, v. 11, p. 391–413.

Marco, S., Ron, H., McWilliams, M.O., and Stein, M., 1998, High-resolution record of geomagnetic secular variation from late Pleistocene Lake Lisan sediments (paleo Dead Sea): Earth and Planetary Science Letters, v. 161, p. 145–160.

Mazaud, A., and Channell, J.E.T., 1999, The top Olduvai polarity transition at ODP Site 983 (Iceland Basin): Earth and Planetary Science Letters, v. 166, p. 1–13.

McDougall, I., Brown, F.H., Cerling, T.E., and Hillhouse, J.W., 1992, A reappraisal of the geomagnetic polarity time scale to 4 Ma using data from the Turkana Basin, East Africa: Geophysical Research Letters, v. 19, p. 2349–2352.

Opdyke, N.D., Lindsay, E., and Kukla, G., 1983, Evidence for earlier date of 'Ubeidiya, Israel hominid site: Nature, v. 304, p. 375.

Picard, L., and Baida, U., 1966, Stratigraphic position of the 'Ubeidiya formation: Israel Academy of Sciences and Humanities Proceedings, no. 4, 10 p.

Stekelis, M., Bar-Yosef, O., and Schick, T., 1969, Archaeological excavations at 'Ubeidiya, 1964–1966: Jerusalem, Israel Academy of Sciences and Humanities, 29 p.

Swisher, C.C., III, Curtis, G.H., Jacob, T., Getty, A.G., Suprijo, A., and Widiasmoro, 1994, Age of the earliest known hominids in Java, Indonesia: Science, v. 263, p. 1118–1121.

Tchernov, E., 1975, The early Pleistocene molluscs of Erk-el-Ahmar: Jerusalem, Israel Academy of Sciences and Humanities, 36 p.

Tchernov, E., 1987, The age of the 'Ubeidiya Formation, an early Pleistocene hominid site in the Jordan Valley, Israel: Israel Journal of Earth Sciences, v. 36, p. 3–30.

Tchernov, E., 1999, The earliest hominids in the southern Levant, *in* Proceedings of the International Conference of Human Palaeontology, Orce, Spain, 1995: Orce, Spain, Museo de Prehistoria y Paleontologia, p. 389–406.

Tobias, P.V., 1966, A member of the genus *Homo* from 'Ubeidiya: Jerusalem, Israel Academy of Sciences and Humanities, 12 p.

Verosub, K., and Tchernov, E., 1991, Résultats préliminaires de l'étude magnétostratigraphique d'une séquence sédimentaire à industrie humaine en Israël, *in* Bonifay, E., and Vandermeersch, B., eds., Les premiers Européens: Paris, Comité des Travaux Historiques et Scientifiques, p. 237–242.

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