

## Magnetostratigraphy of the hominid tool-bearing Erk el Ahmar Formation in the northern Dead Sea Rift

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### ABSTRACT

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The Erk el Ahmar Formation was sampled for paleomagnetic measurements. Seventy-eight samples were taken from the type locality section. The formation includes a polarity sequence (base to top) of RNRN (R = reverse, N = normal). Assuming the paleontological and palynological age of 1.5–2 Ma determined by Tchernov and Horowitz, the sequence is correlated with the absolute polarity time scale. The reversal of 2.04 Ma is within the studied section and the upper normal section may correlate with either the Olduvai or the upper Reunion (2r-1) subchrons. Sedimentation rate during the period of normal polarity between the two reversals is 1.56 mm/year according to the first correlation or 2.35 mm/year according to the second alternative.

Human artifacts which are found throughout the outcrops of Erk el Ahmar indicate a pre-Ubeidiya (and therefore the earliest) hominid presence outside Africa about 2 Ma ago.

### INTRODUCTION

The oldest well-studied prehistoric site outside Africa is Ubeidiya (Tobias, 1966; Tchernov, 1986), located in the central Jordan Valley, Israel, about 3 km south of the Sea of Galilee, on the west bank of the Jordan River (Fig. 1). The valley is a graben which was formed as part of the Dead Sea Transform system. South of the Ubeidiya area there are some well-exposed outcrops of lacustrine and fluvial sediments of the Erk el Ahmar Formation (Erk el Ahmar) (Horowitz, 1979). No exposed contact has been found between the Ubeidiya and Erk el Ahmar formations, and no radiometric age has been determined, however assemblages of mollusca and pollen indicate that the Erk el Ahmar Fm. is older than Ubeidiya (Tchernov, 1975; Horowitz, 1979).

Flint artifacts which were identified as hominid-made tools were found in outcrops of the Erk el Ahmar Fm. (Fig. 2). Horowitz was the first to report about human artifacts found there: "Recently, some artifacts were found in the Erk-el-Ahmar Formation" (Horowitz, 1979, p. 141). Later Verosub and Tchernov (1991) reported, "Recently, two pebble tools have been found at an archaeological site on the west side of the Jordan Valley in Israel. The sediments in which the tools were found are apparently equivalent to those of the Erq-el-Ahmar Formation." As a newly found pre-Ubeidiya tool-bearing strata, the age determination of the Erk el Ahmar is crucial to the study of human evolution and migration out of Africa. Two occurrences of pre-Ubeidiya sites were described from Lebanon (Hours, 1975).

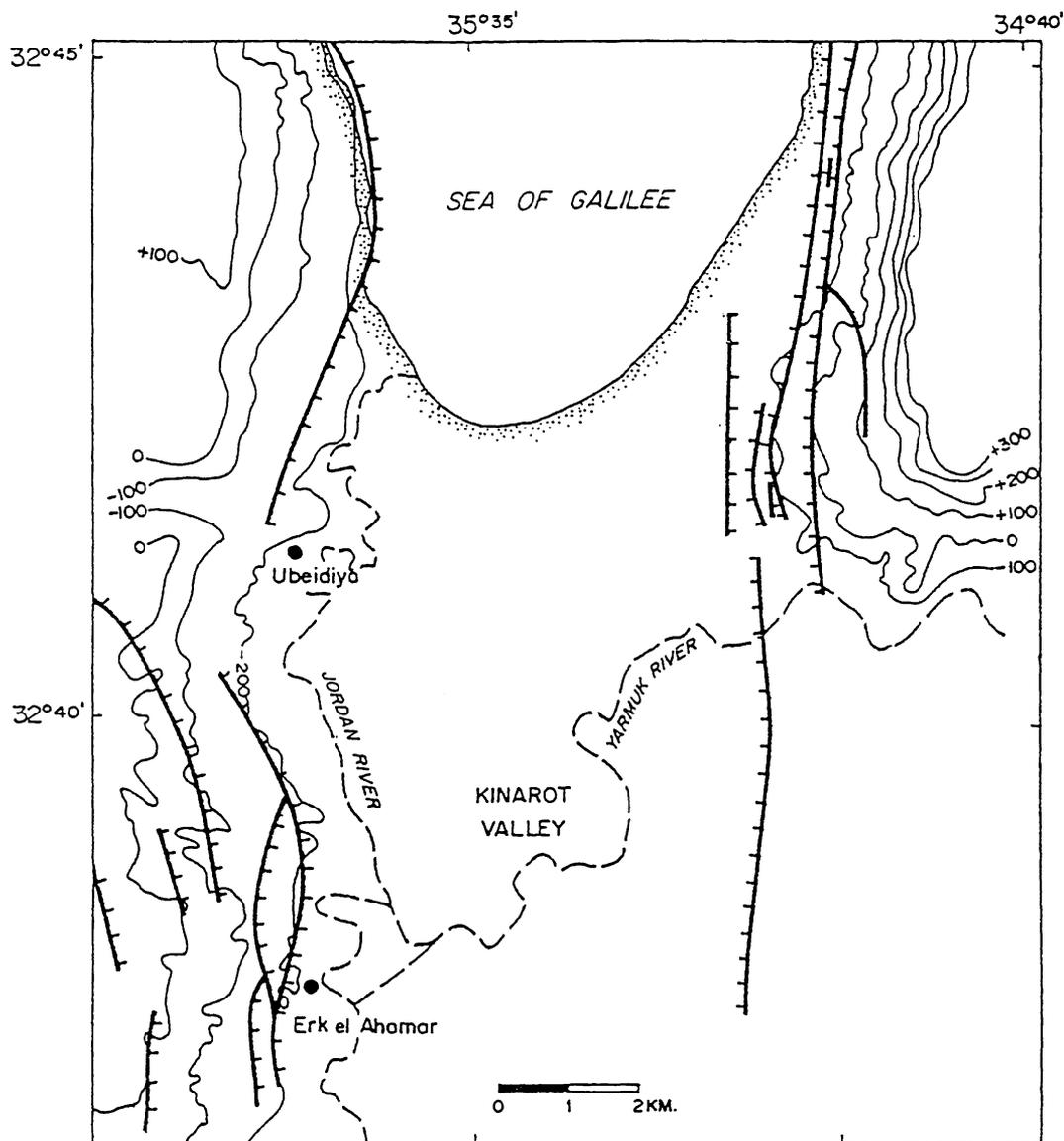


Fig. 1. Location map.

The geological and radiometric data leave a very large uncertainty for the age of human migration out of Africa. The present study intends to reduce this uncertainty. We report detailed magnetostratigraphic data from a major part of the Erk el Ahmar type locality section which provide a tight constraint on its age. This report is part of a regional tectonostratigraphic study carried out by D. Braun.

### GEOLOGY

The Jordan Valley sedimentary sequence, the prehistoric remains, and the strata bearing mammal assem-

blages attracted many investigators since the early years of this century. Among them are Blanckenhorn (1914) and Blanckenhorn and Oppenheim (1927) who assign a Late Pliocene age to the sequence which is currently referred to as the Erk el Ahmar and Ubeidiya formations. Picard (1932) and Picard and Baida (1966) suggest an Early-Middle Pleistocene age to the same sequence, and Schulman (1962) describes the overall geology of the central Jordan Valley.

Tchernov (1975) concludes that the Erk el Ahmar is older than the Ubeidiya Fm., to which a paleontological age of 1.4 Ma was attributed (Tchernov, 1986). His conclusion was based on the study of the mollusca



Fig. 2. The type locality of the Erk el Ahmar Formation looking southward. The Lisan overlies the section unconformably.

assemblages. Horowitz (1989) correlated the pollen assemblages of the Erk el Ahmar palynozone (Q III) with deep-sea cores and estimates the age of the pollen to be 1.5–1.85 and perhaps up to 2 Ma (Horowitz, 1990, personal communication).

The Erk el Ahmar Fm. consists of clays, silt, sand, conglomerate, and some carbonate layers. In places, the section is very rich in molluscs. Flora and fish remains are also abundant. The hominid tools were found in the upper part of the sequence.

The Erk el Ahmar Fm. has been faulted and tilted by the Dead Sea Transform and graben tectonism. It is usually tilted eastward with dips of 15° up to vertical. The studied section dips about 20° eastward. The section is truncated by an angular unconformity and overlain in places by the horizontal Lisan of Würm age (Begin et al., 1974), a pre-Lisan conglomerate, and in one locality by the Yarmuk Basalt. K–Ar age of the Yarmuk Basalt is 0.6 Ma (Heimann, 1990).

The base of the Erk el Ahmar overlies the Cover Basalt (Horowitz, 1979). The age of the Cover Basalt is 5.1–3.3 Ma (Heimann, 1990).

## METHODS

Sampling included two outcrops of the Erk el Ahmar Fm. at Israel grid coordinates 20292/22697 and a higher section at 20340/22685.

The soft, friable sediments were sampled by carving a cubic pedestal and then placing a glue-coated plastic capsule over it. Both the glue and the capsule are nonmagnetic materials. The orientation was determined with a Brunton compass before removing the sample. Each one of the 38 sampling points included 2 individual samples. The sampling points were spaced vertically about 1 m apart.

Remanent magnetization of all samples was measured with a three-axis superconducting magnetometer “2G Enterprise” at the Institute for Petroleum Research and Geophysics, Holon.

The natural remanent magnetism (NRM) was measured first and then the specimen was subjected to stepwise demagnetization by alternating field (AF) with increasing intensity, starting with 5 mT (milli-Tesla) and going up to 40–80 mT in 5- or 10-mT increments. A measurement was made after each demagnetization step.

Results are presented by orthogonal vector plots (Fig. 3) which illustrate the direction and normalized intensity ( $J/J_0$ ) of the remanent magnetic vector before demagnetization (the natural remanent magnetism) and as demagnetization proceeds (Zijderveld, 1967). The vector end is projected onto two orthogonal planes, horizontal and vertical; solid symbols denote the true inclination (projected onto the vertical plane), and open symbols denote the declination (projected onto the

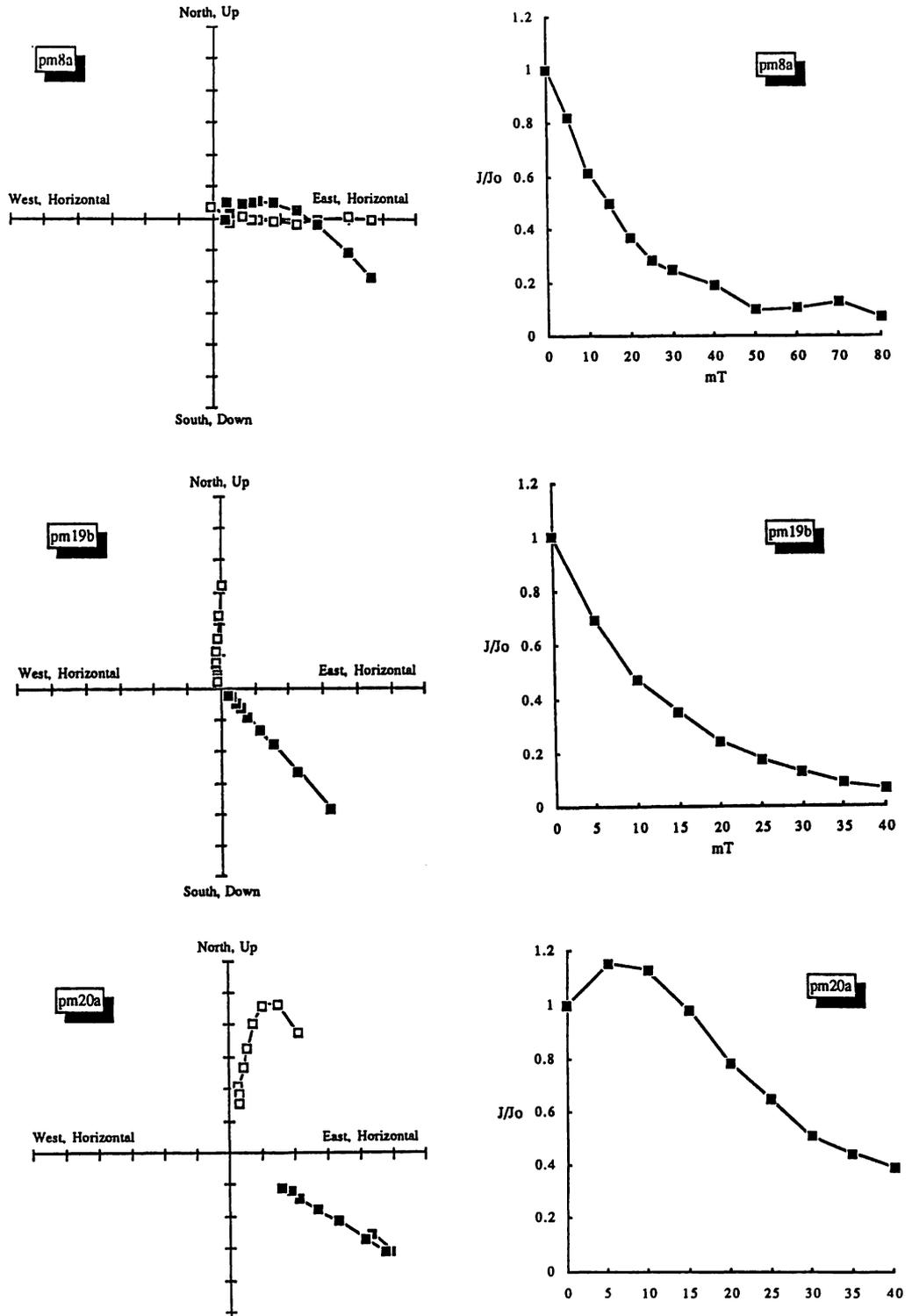


Fig. 3. Orthogonal vector plots and normalized intensities ( $J/J_0$ ) of typical examples of the Erk el Ahmar Formation. Open symbols denote declinations, solid symbols denote inclinations. Sample pm8a — anomalous direction of transition, pm19b — normal polarity, pm20a — reverse overprint on normal polarity, pm34b — reverse polarity, pm38b — normal overprint on reverse polarity.

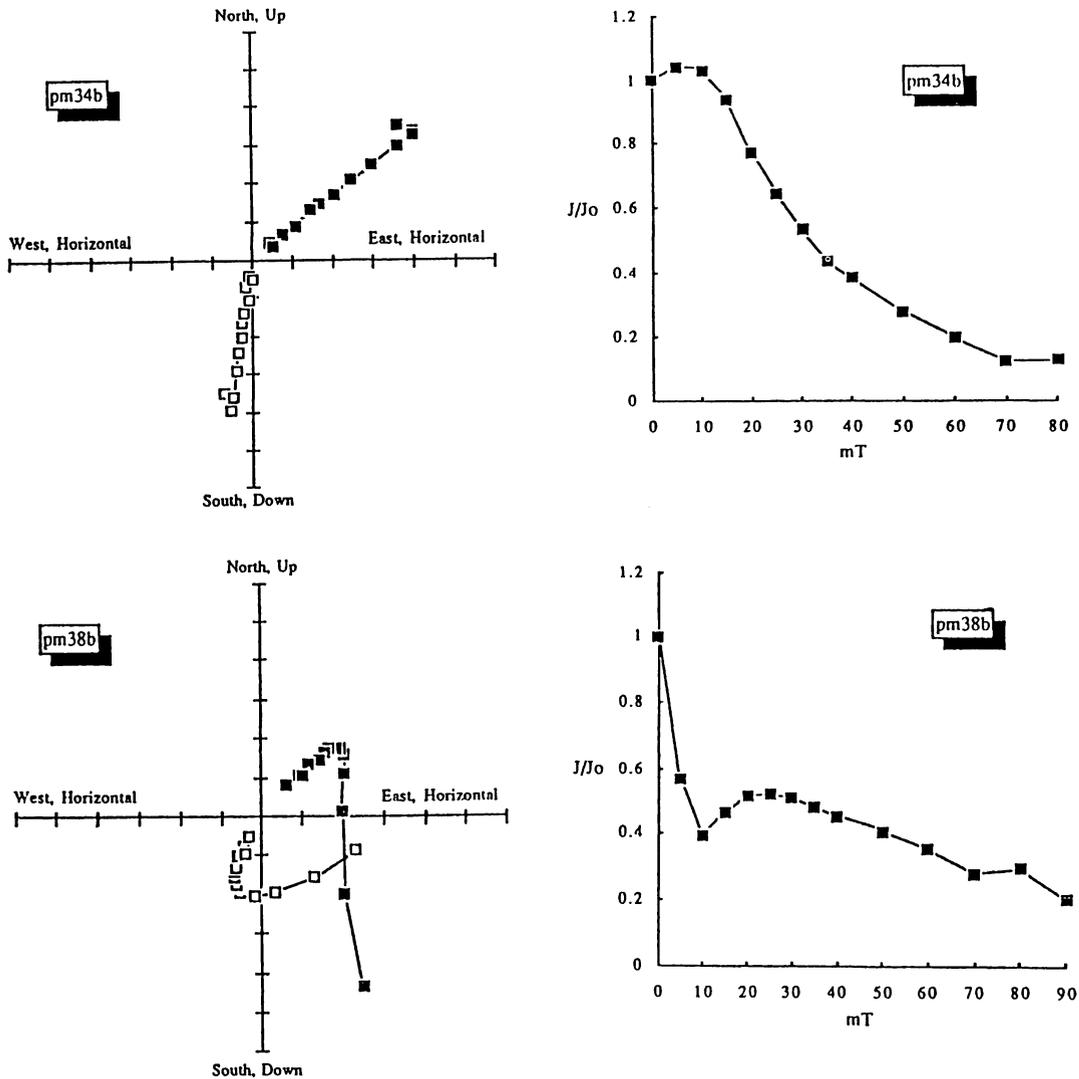


Fig. 3. cont.

horizontal plane). The directions of the characteristic vectors have been retilted to account for the tectonic dipping of the bedding planes. A stereographic projection is used to illustrate the distribution of directions where each reading is taken as a unit vector. The normalized intensity of the remanent vector ( $J/J_0$ ) versus the field (AF) is illustrated on a separate graph.

## RESULTS

Most of the samples show two-component magnetization: a low to moderate coercivity component (most likely viscous remanent magnetization), typically re-

moved by a peak field of 10–20 mT and a stable characteristic vector (Fig. 3). The rest of the samples are single-component. The mean destructive field is about 20–30 mT with a coercivity spectrum typical of magnetite.

The demagnetization curves of the sediments show that all the samples were stably magnetized (Fig. 3). The distribution of the inclination along the columnar section (Figs. 4,5) clearly shows distinct sections of normal (N) and reverse (R) polarities. The sequence in the northern outcrop is RNR and in the southern outcrop it is RN. The average declination of all the samples is  $12^\circ$  and the inclination is  $39^\circ$  ( $R = 0.9190$ ,  $k = 12.3$ ,  $\alpha_{95} = 5^\circ$ ).

DISCUSSION

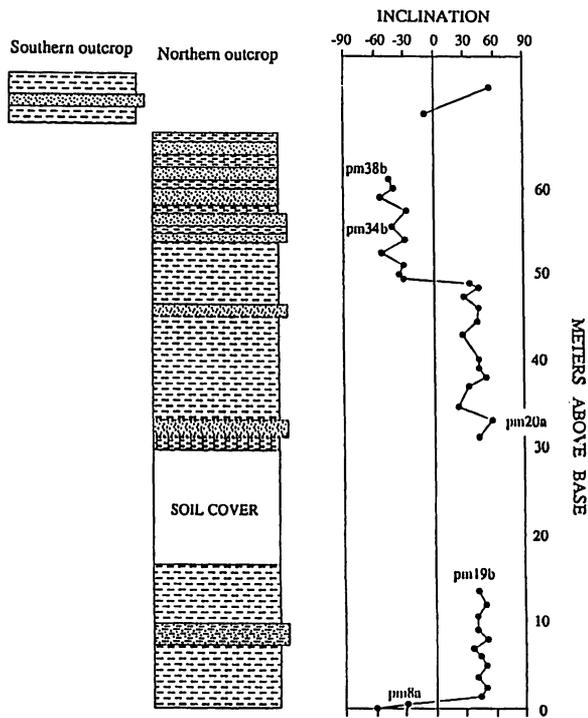


Fig. 4. The distribution of magnetic inclinations in the studied section of the Erk el Ahmar Formation.

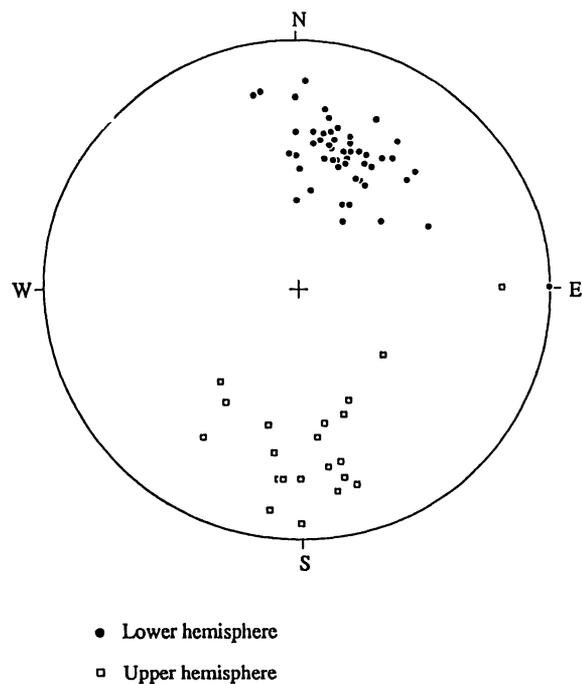


Fig. 5. Equal area projection of magnetic field directions of the Erk el Ahmar Formation.

The recorded magnetostratigraphy of two outcrops of the Erk el Ahmar Fm. includes reverse-normal-reverse (RNR) in the northern and reverse-normal (RN) in the southern outcrop. The position of the outcrops indicates that the southern outcrop is a higher section of the formation and therefore the complete sequence is RNRN. The presence of mixed polarities of antipolar means rules out postdepositional resetting of the magnetization.

The expected field direction of the Plio-Pleistocene is northward declination and 50° inclination. However, after tectonic correction, the inclination of the average direction here is 39°, most probably due to a shallowing effect typical of fine-grain clastics (e.g., Levi and Banerjee, 1990). The deflection of the declination by 12° from the expected may be ascribed either to clockwise tectonic rotation about a vertical axis or to incomplete averaging of secular variations of the field direction.

Correlation between this sequence and the absolute magnetic polarity time scale (Harland et al., 1982) requires an independent lower and upper constraint on the age of the sequence or at least one absolute age determination within the studied sequence.

No radiometric ages of this clastic formation have been reported. The paleontological and palynological constraints of 1.5–2 Ma (Tchernov, 1986 and Horowitz, 1989) are therefore adopted in order to correlate the section to the absolute polarity time scale.

Two possible correlations are proposed:

- The upper section of normal polarity correlates with the Olduvai subchron (Fig. 6A).
- The upper section of normal polarity correlates with the upper Reunion (2r-1) subchron (Fig. 6B).

In either case, the reversal of 2.04 Ma at the base of 2r-1 is within the studied section. It should be noted that the difference between the two possible correlations is only 5%.

It is concluded that human artifacts which are found throughout the outcrops of Erk el Ahmar indicate a pre-Ubeidiya (and therefore the earliest) hominid presence outside Africa about 2 Ma ago.

Average sedimentation rate during the period of normal polarity between two reversals is ~47m/30,000 years = 1.56 mm/year according to the first possibility or ~47m/20,000 years = 2.35 mm/year according to the second.

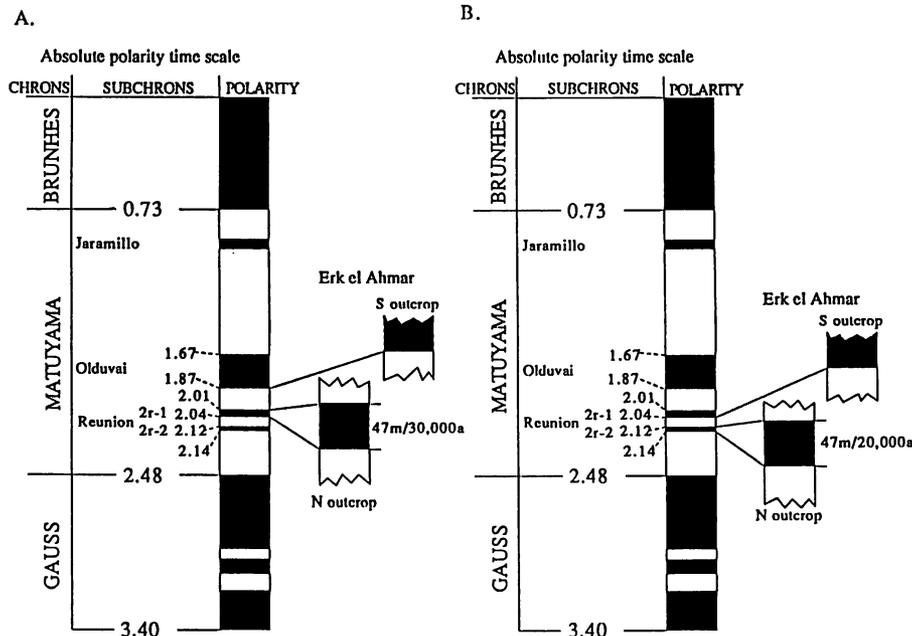


Fig. 6. Two possible correlations of the magnetostratigraphic sequence of the Erkel Ahmar Formation with the absolute polarity time scale (Harland et al., 1982). Ages are in Ma; black is normal polarity, white is reverse.

#### ACKNOWLEDGMENTS

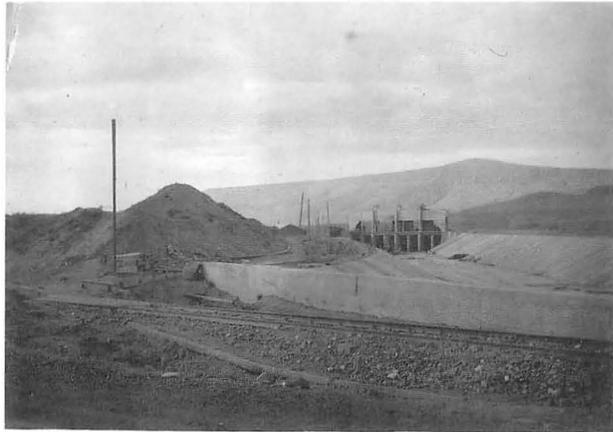
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Western slopes of the Jordan Valley, south of Lake Kinneret. View to the south of Bitania, showing Nahal Yavne'el on the right. *Photo: L. Picard, 1929.*



Naharayim hydroelectric station, south of Yarmuk River.  
*Photo: L. Picard.*



Zemah-Damascus railway, crossing Yarmuk River. *Background: Raqqad Basalt. Photo: L. Picard, 1929.*