The Near East Archaeomagnetic Dating Curve (NEAC):

A Complementary Geochronometer for Building Robust Archaeological Chronologies

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Introduction: The Dating Dilemma

Archaeomagnetism, the study of the Earth's ancient magnetic field as recorded by heat-treated anthropogenic objects, is a crucial source of paleomagnetic data for modeling geomagnetic field behavior during the Quaternary.

These same data can be compiled to construct regional reference curves of field intensity (strength) and directional variability through time, which can then be used as geochronometers suitable for building more robust archaeological chronologies. This approach is particularly significant for time periods when other dating techniques provide ambiguous age results or lack the narrow standard deviations necessary for meticulous interpretation of human events.

This research utilizes Bronze and Iron Age Near Eastern pottery, fired brick, and clay ovens to demonstrate the applicability of archaeomagnetic dating in order to address the radiocarbon dating controversy surrounding the first millennium B.C.E. in the Levant. During this period, the radiocarbon curve is marked by a number of plateaus and De Vries effects that cause bimodal age determinations, which have resulted in chronological contention in the Near East archaeological community (Fig. 1).

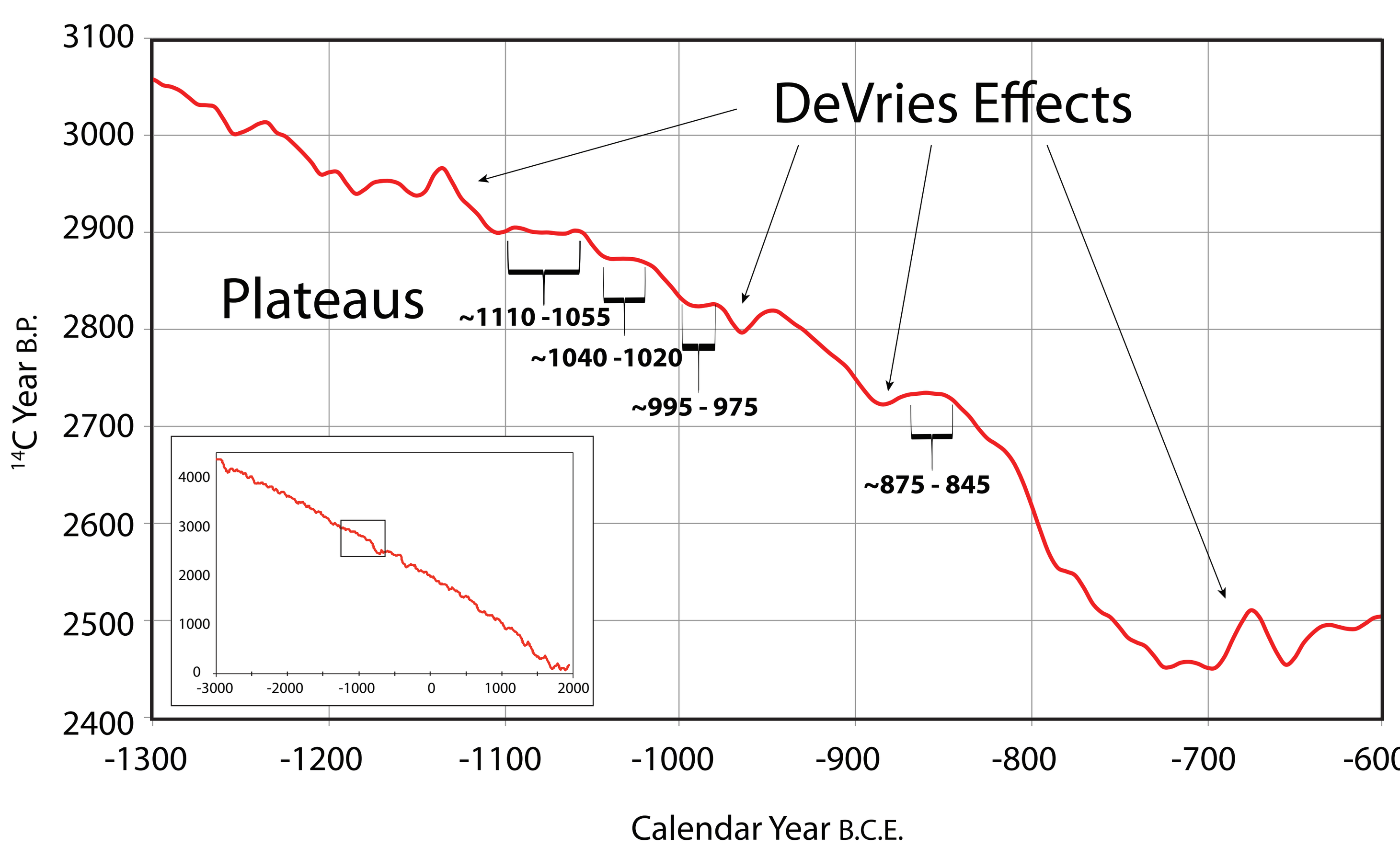

Fig. 1. IntCal13 radiocarbon calibration curve for the Northern Hemisphere for the 13th through 7th centuries B.C.E. highlighting plateaus and De Vries effects, which cause indeterminant age distributions. Inset is curve for the last 5000 years. Figure reproduced from Fig. 7 in Stillinger et al., 2016.

Near East Archaeomagnetic Curve (NEAC)

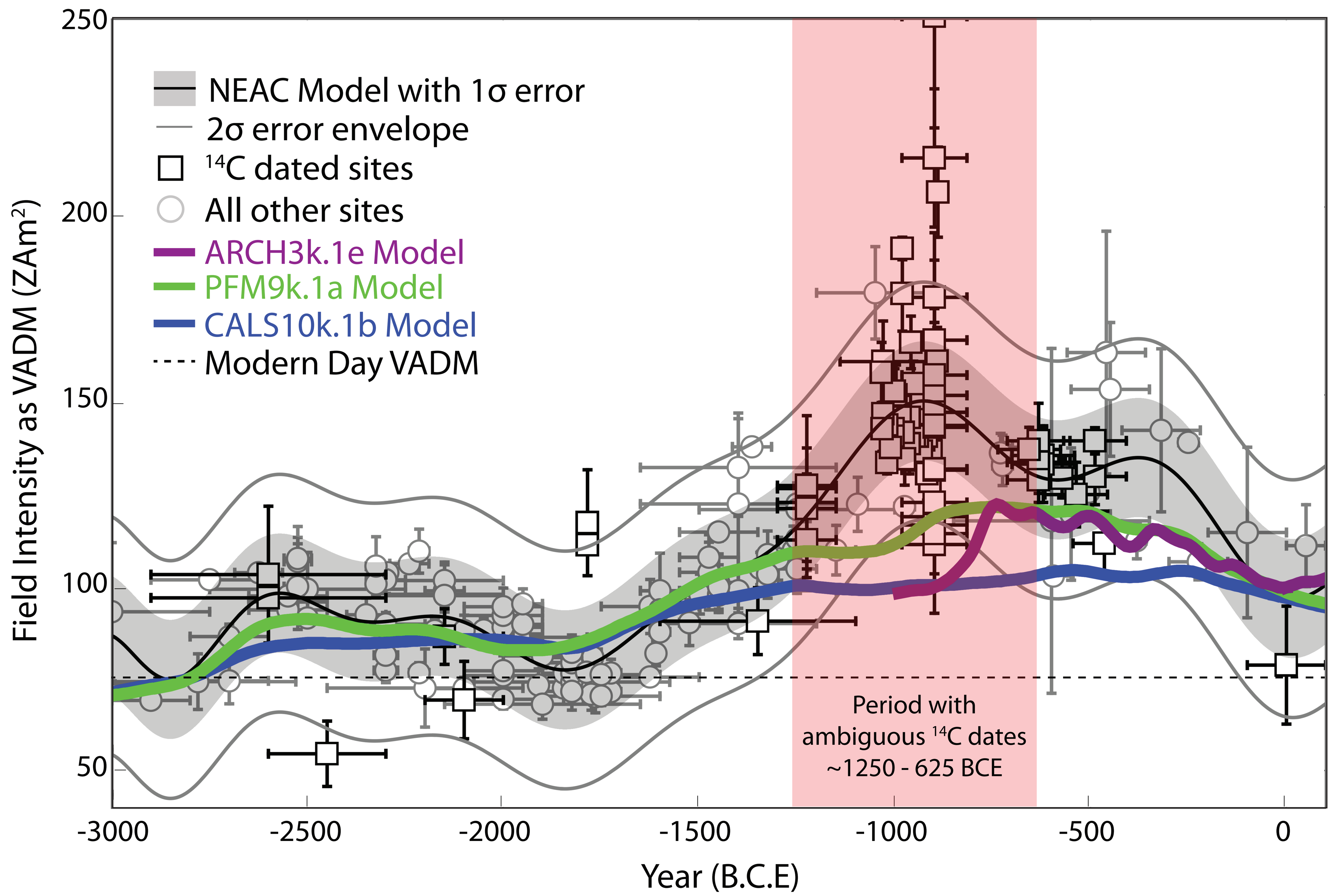

Fig. 2. Near East Archaeomagnetic Curve (NEAC) modeled using procedures outlined in Stillinger et al., 2015 and compared against three time-varying, geomagnetic field reference models. Open black squares/grey circles indicate data points calibrated with ^{14}C and relative dating methods, respectively. Virtual Axial Dipole Moment (VADM) represents the Earth's total field strength generated by the core that gives rise to a locally measured intensity in microTesla. The ARCH3K.1e (purple) field model is based on only archaeomagnetic data for the last 3000 years and published up until 2009. This model is strongly biased to the Northern Hemisphere and contains data from some studies that are outdated in terms of methodology. The CALS10k.1 (blue) field model covers the last 10,000 years and includes all archaeological, sediment, and lava data up until 2011. The PFM9k.1a (green) field model is similar to the CALS10k model but incorporates new data treatments and sedimentary data. It is notable that while all of these models show the same broad trends in geomagnetic field strength as the NEAC model, none of them appear to capture the dramatic increase in field strength that is recorded by Near East archaeological materials at ~1000 B.C.E. Figure modified from Figure 10 in Stillinger et al., 2016. See references therein for global models.

Methods & The Way Forward

The NEAC model was constructed using regionally specific archaeomagnetic data compiled from this research, the GEOMAGIA50 online paleomagnetic database, and other recent archaeomagnetic studies (see Stillinger et al., 2016 and references therein). Model data were constrained to studies employing the IZZI paleointensity protocol or other double heating method that applied pTRM checks and anisotropy corrections (with the exception of studies using the Triax measurement method).

The NEAC model is based on a polynomial fit of these data, which produced the lowest residual standard deviation without introducing spurious features in the reference curve from outlying data points. This polynomial model also produces a smoother reference curve and a fixed standard deviation in comparison with the moving window average model, which has been used in other studies. Both modeling methods produce similar results.

Contributions from the archaeological community of more high-fired materials from successive occupational layers with strong stratigraphic controls, undisputed relative dates, and/or association with other absolutely dated materials, is necessary to further refine the NEAC model, especially for the period with ambiguous radiocarbon dating (Fig. 2 - red zone) or periods lacking in paleomagnetic data (i.e. the early first millenium B.C.E.).

As more high-quality archaeomagnetic data is gathered, the NEAC dating curve will provide archaeologists with a new complementary or alternative dating method for dating archaeological sites and materials from periods where radiocarbon analysis or relative dates are disputed.

Fig. 3. Artifacts from Khirbet Summeily, Israel. Diagonstic items such as these are typically used for relative dating of archaeological sites, an important but often subjective dating method. The pottery can also be utilized in archaeomagnetic dating. Figure reproduced from Fig. 6 in Stillinger et al., 2016.

References

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