Looking for a cryptochron: high resolution magnetostratigraphy of 15R, 15N, and 16N in calcareous marls near E/O boundary at Contessa and Massignano quarries in Italy's Umbria-Marche region

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INTRODUCTION

The fold-and-thrust belt of the Northeastern Apennines contain a continuous sequence of limestones, clays, and calcareous marls spanning the lower Jurassic to the upper Miocene. Several magnetostratgraphic studies conducted in stratographic sections around the Oligocene-Eocene boundary in the Marche and Umbria regions of Northern Italy sequence show a correlation of the overall magnetostratigraphy with the marine magnetic polarity sequence. In addition to the main magnetic polarity intervals, called chrons, the paleomagnetic record includes short reversals known as cryptochrons or "tiny wiggles". One study attributes these to geomagnetic intensity fluctuations rather than short polarity chrons (Cande and Kent 1992). Using an average sampling interval of 50 cm Bice and Montanari (1986) showed evidence of a cryptochron in the upper part of chron 16N in the Global Stereotype Section and Point (GSSP) for the Eocene-Oligocene boundary at Massignano quarry near Ancona. In a similar study at the Massignano GSSP, Lowrie and Lanci (1994) did not find this "fluctuation" using an average sampling interval of 70 cm.

In 1993 a 40m core was drilled behind the quarry wall at Massignano quarry. 2.54 cm diameter cores were taken at an average spacing of 12cm from this MASSICORE. This made possible a high resolution magnetostratigraphic analysis for a 40 m section of the Eocene/Oligocene GSSP at Massignano quarry (Lanci et. al, 1996). The MASSICORE identifies two biotite layers in the same section my samples correlate to. The study correlates the biotite leyer at the 32.00m depth with the layer at 8.00 m. While the larger MASSICORE magnetostratigraphic section does correlate with the magnetostratigraphy of previous coarser resolution studies, on the scale of the few meters this study covers, there is no correlation. If biotite layer at depth 32.00m were matched with the biotite layer at 5.80m, then there is a correllation in the magnetostratigraphy.

Using an average sampling interval of 15 cm at the Massignano GSSP this study found evidence for the cryptochron. With a sampling interval of 9 cm at the correlated classic sequence of Contessa (Gubbio) preliminary results support the existence of the cryptochron. That the cryptochron could be found indicates that the polarity reversal is too long to be explained by a small intensity fluctuation.

METHODS

I collected samples in the sections of Contessa (Gubbio) and Massignano (**fig. 1 map**) which are located in quarries exposing the calcareous marls of the uppermost part of the Scaglia Variegata formation (upper Eocene). The section in the abandoned quarry of Massignano has been dated using planktonic Foraminifera, radiometric age dating and magnetostratigraphy and is known to cover a time span between 30 and 37 Ma (Montanari et al., 1988; Silva et al. 1988). The quarry in the Contessa valley is active and has been dated similarly, though not as extensively, and it covers a continuous interval comprising the upper Eocene, the Oligocene, and the lower Miocene, from 37 to 19 Ma. The Eocene-Oligocene boundary is contained in a sequence of pelagic calcareous marls with thin interbeds of biotite-rich volcanic ash and clay-rich marls.

I took samples from only about 4 meters of each quarry, 10-15m below the Eocene/Oligocene boundary. This interval corresponds to 35.5 ±0.5 Ma and to chrons 16N, 15R, and the bottom of 15N (**fig. 2 corresponding strat columns**). The short reversal was found by Bice and Montanari just below chron 15R in samples from the Massignano quarry (1988). This short reversal may have been verified in the Contessa quarry section by Nocchi et al. (1986) but not in either quarry by Lowrie and Lanci (1994). Lowrie and Lanci suggested that a resolution of sample spacing of 5-10 cm would be required to be able to detect the cryptochron.

Using the stratigraphic work done on previous studies (Clymer, 1995; Montanari, 1987; Lowrie et al., 1982) I determined that paleomagnetic core samples should be taken from 4-8 meters on the stratigraphic section of the Massignano quarry and from 217-219 meters on the stratigraphic section of the Contessa quarry. Oriented hand samples were taken from each quarry. At each quarry I identified bedding plane surfaces and I measured and marked the strike direction on each 5-10 cm^3 block sample before it was chiseled out of the quarry wall. The beds uniformly dipped west 18° at the Massignano quarry and 65° west at Contessa quarry. The strikes ranges from N292°W-N330°W at Massignano and S289°W-S308°W at Contessa quarry. The Contessa quarry was still active and the quarry wall was more fresh so was much easier to identify bedding planes and take samples than at Massignano quarry. Therefore the average sample spacing at Massignano was 15 cm and the average spacing at Contessa quarry was 9 cm. Special care had to be taken at both sites to assure that bedding planes were not confused with the fractures due to the abundant trace fossil of zoophycos.

Depending on the size and integrity of each hand sample 1-6 cores were taken from each of them. Most hand samples yielded 2-3 cores. Each core was one inch in diameter, the standard for paleomagnetic work, and anywhere from one to four inches long. Some of the cores broke as they were being drilled; these were glued back together using a non-magnetic vinyl glue or with Zircar alumina cement.

I arranged with Dr. Joe Kirschvink and John Holt at the California Institute of Technology to use their cryogenic magnetometer. I cut all 185 of my core samples to a length of 2.54 cm in order to fit the magnetometer. The samples were cut dry as liquid lubricant destroys the soft samples.

These calcareous marls have extremely weak magnetic moment. The natural remnant magnetization (NRM for the cores is on the order of 10^{-6}emu. That's only two orders of magnitude higher than the magnetic moment for the sample holder for the magnetometer, which was usually around 10^{-8}emu. On a few test samples I found that heating them to 250°C removed the overprinting due to goethite since this is the Curie temperature for goethite. The magnetic coercivity for magnetite is 200 gauss so to remove overprinting due to magnetite and goethite on the samples I demagnetized each sample using step-wise alternating field (AF) demagnetization from 0 - 800 gauss steps, 800 gauss being the limit of Caltech's magnetometer, and after the 100 gauss AF demagnetization step I heated up each sample to 250°C. Then I proceeded on with the rest of the AF demagnetization steps. This was very successful although very time consuming. In order to save time I performed this thermal step on only half of the Massignano quarry samples and to only one of the Contessa quarry samples. In some of the initial samples the overprinting due to goethite appeared to be removed in the last two or three AF steps and thus the thermal demagnetization step didn't seem necessary. Later results showed that the thermal demagnetization step produced superior results so all of the remaining cores will be demagnetized using the thermal demagnetization step.

RESULTS AND CONCLUSIONS

By correlating the magnetostratigraphic columns according to the biotite layers at 218.00 m at Contessa quarry and 8.00 m at Massignano quarry there is a good correlation between this study and the previous low resolution studies. The top of chron 16N correlates well in all of the studies except the MASSICORE study not yet published (Lanci et. al, 1996). Also the bottom of chron 15N correlates well with the Massignano studies (**fig. 4**). Fisk (1996) identified more biotite layers in Contessa quarry than any previous study and, using geochemistry, correlated them to the biotite layers at Massignano. By uniformly stretching the Contessa quarry stratigraphic column such that biotite layers at 10.81m, 9.88m, and 9.48m in Contessa quarry match the biotite layers at 8.00m, 7.2 m, and 5.8 m respectively at Massignano quarry the correlation between this study and the other low resolution studies becomes more obvious (**fig 5 corresponding magnetic strat columns from Massignano quarry studies)**

It could be that the overprinting due to goethite has not been removed from the samples and that the data in this study is flawed. There is, however, a correlation between the magnetostratigraphy in this study and in the low resolution studies. This correlation will allow for the existence of the cryptochron near the top of chron 16N .

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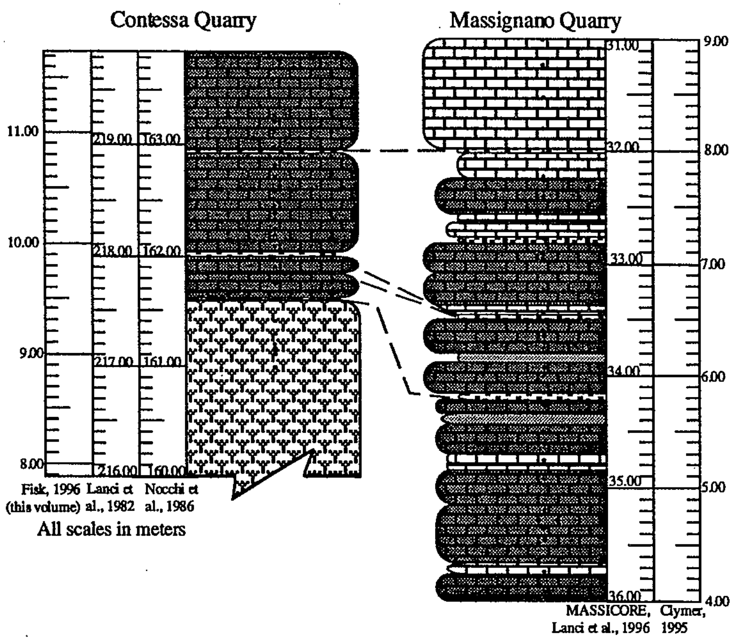
Fig. 2: Stratigraphic sections from the GSSP in the Massignano quarry and the classic section of the Contessa quarry. The columns here are drawn to same scale and aligned according to biotite levels C. Q. 10.81m = M. Q. 8.00m (Fisk, 1996)



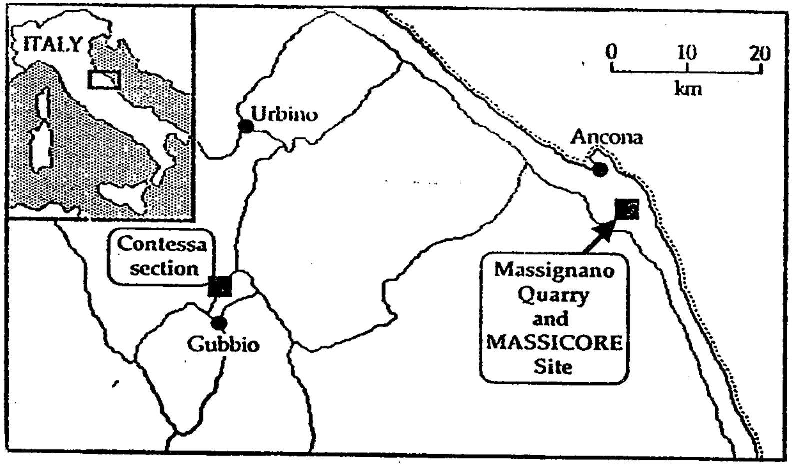


Fig. 4: The same stratigraphic sections after stretching the Contessa Quarry column to best fit corresponding biotite-rich beds in the Massignano GSSP (Fisk, 1996).

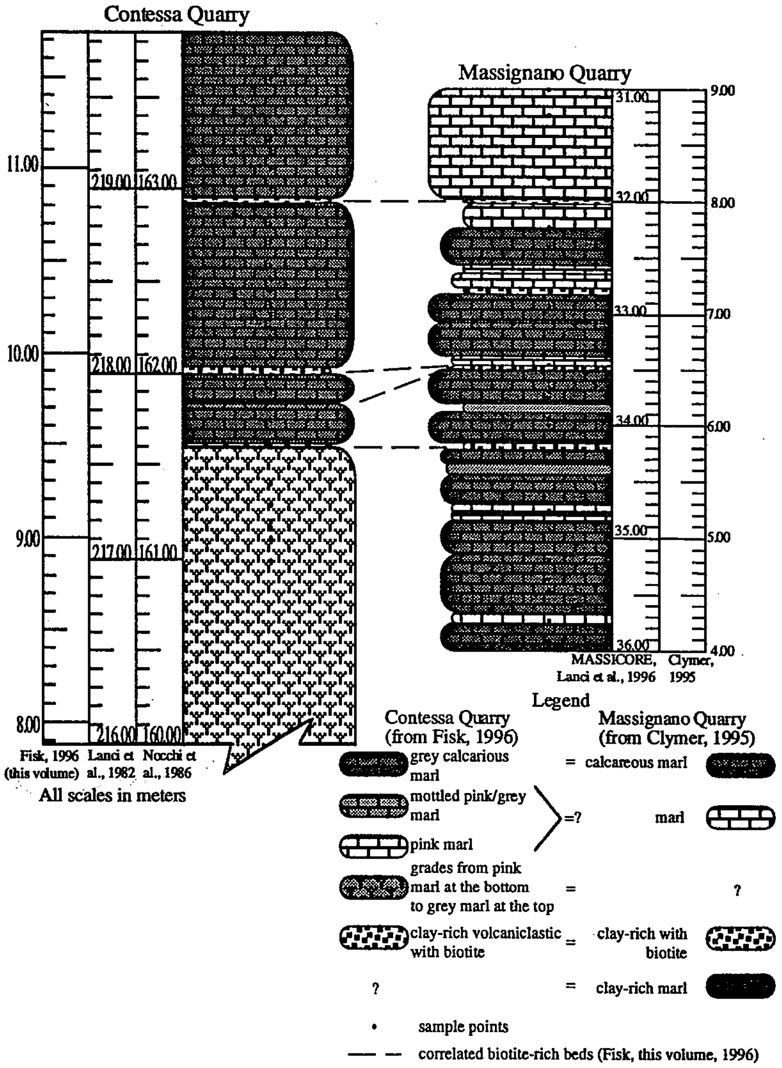


Fig. 3: Paleomagnetic correlation between the classic section of the Contessa quarry and the GSSP in the Massignano quarry according to biotite-rich beds (Fisk, this volume).

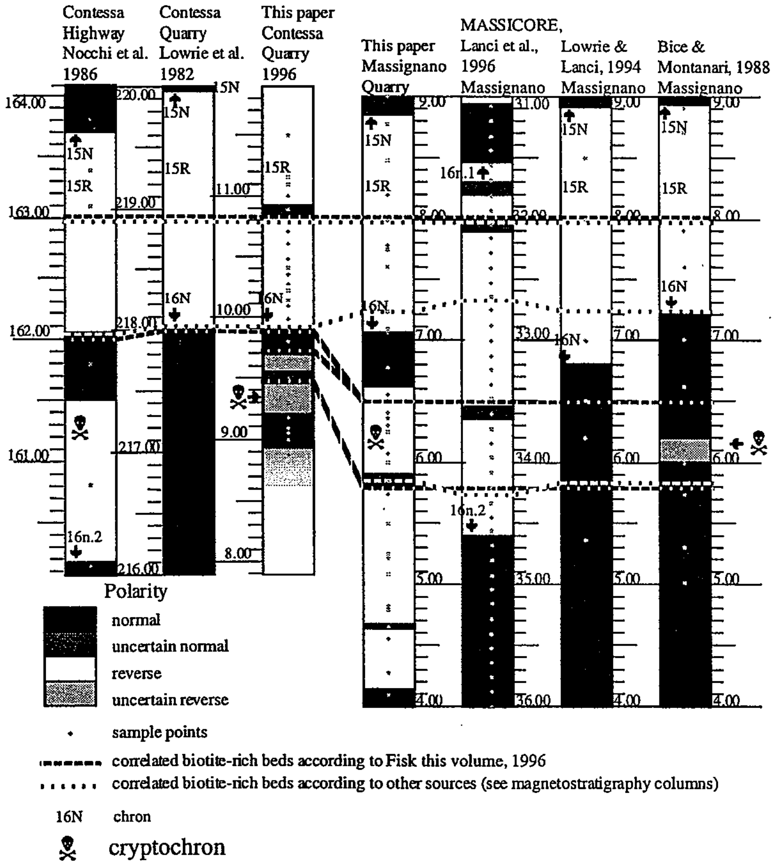


Fig. 5: Paleomagnetic correlation between the classic section of the Contessa quarry and the GSSP in the Massignano quarry corrected for best fit with the biotite-rich beds.