MAGNETIC STRATIGRAPHY AND TECTONIC ROTATION OF THE UPPER PALEOCENE PATTIWAY FORMATION, CALIENTE RANGE, SAN LUIS OBISPO COUNTY, CALIFORNIA

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ABSTRACT

The Pattiway Formation consists of over 1500 m of deep-marine siltstones and sandstones with minor conglomerates exposed in fault blocks in the southern Caliente Range. It yields late Paleocene molluscs, including *Turritella infragranulata pachecoensis*, and Ynezian Stage benthic foraminifera. Magnetic samples of the formation showed a remanence held mostly in magnetite with goethite overprints, which is entirely reversed in polarity, and rotated approximately 60° clockwise. This rotation suggests that the southern Caliente Range is part of the highly rotated terranes of the Transverse Ranges to the south. Based on correlation of the Pattiway Formation with other Paleocene sections with the same fauna, we correlate it with magnetic Chron C26r (58.0-60.9 Ma).

INTRODUCTION

The strata now known as the Pattiway Formation consist of about 1500 m of marine siltstone, sandstone and conglomerate exposed in the most southeasterly part of the Caliente Range, San Luis Obispo County, California (Fig. 1). These strata were first mapped by Eaton et al. (1941), who thought they might be Oligocene in age. Hill et al. (1958) mapped and described the unit in greater detail, and named it the Pattiway Formation, after a now-defunct town site nearby. They mentioned a benthic foraminiferal fauna from the unit which indicate deposition at bathyal depths, but the foraminifera are only suggestive of an age range from Cretaceous to Eocene. Based on the similarities with other units, they argued that an Eocene age was more likely.

Vedder and Repenning (1965) remapped the

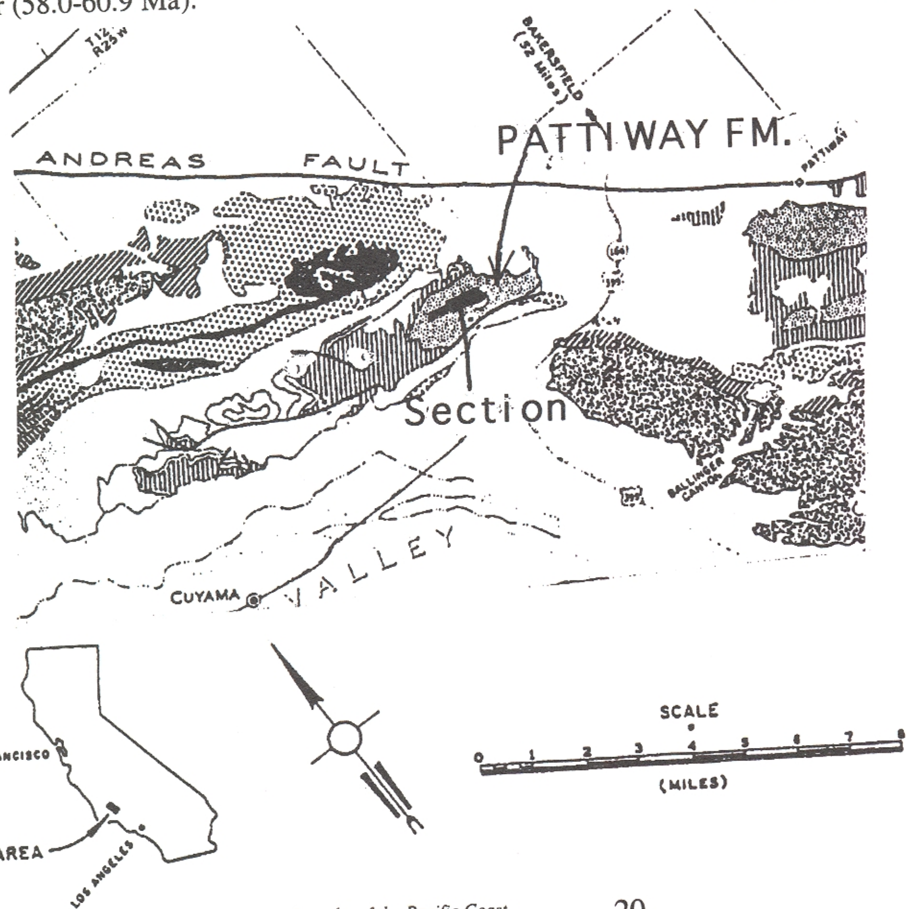

Figure 1. Index map showing location of Pattiway Formation and measured section (modified from Hill et al., 1958).

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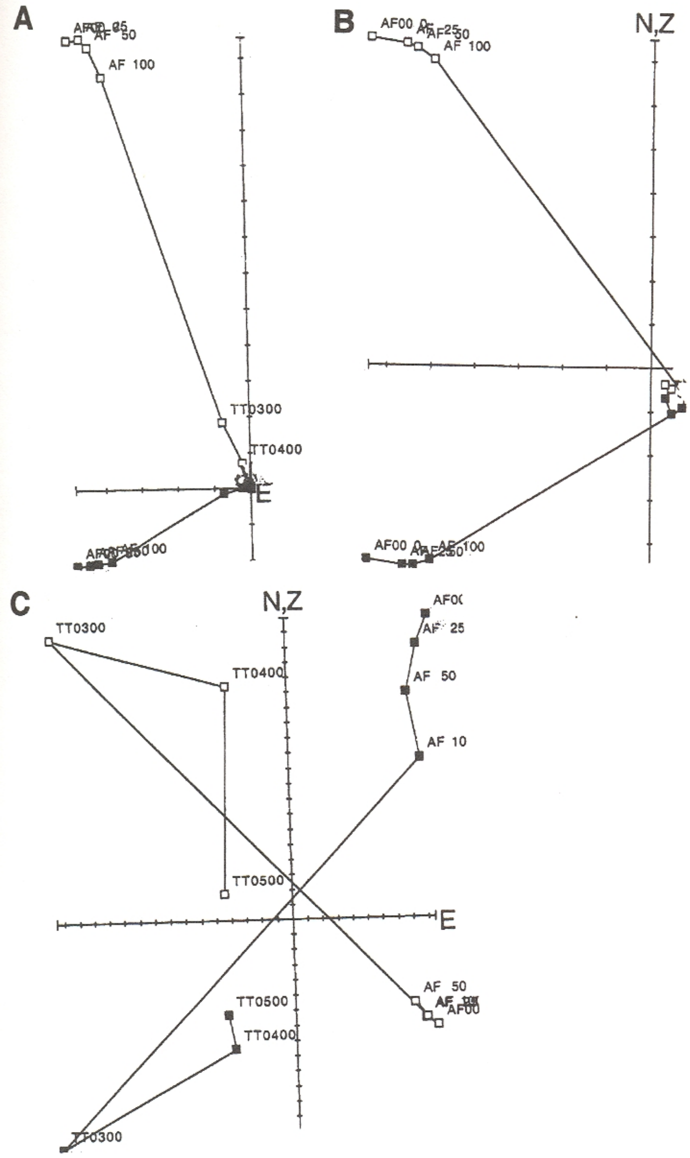


Figure 2. Orthogonal demagnetization ("Zijderveld") plots of representative samples. Solid squares indicate horizontal component; open squares represent the vertical component. Demagnetization steps indicated by "AF" and demagnetization field (in Gauss) and "TT" and thermal step in degrees Centigrade. Each division equals 10^{-7} emu.

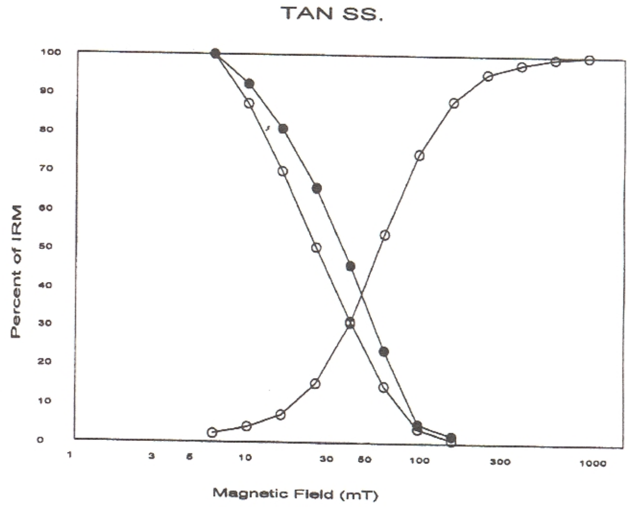


Figure 3. IRM acquisition and Lowrie-Fuller tests of a representative sample. Open boxes are IRM steps; solid boxes are ARM values. The IRM nearly saturates about 300 mT (millitesla), showing that the remanence is carried mostly by magnetite. The ARM is more resistant to AF demagnetization than the IRM, showing that the grains are single-domain or pseudo-single-domain.

Pattiway Formation and first indicated that it had yielded Paleocene molluscs. Dibblee (1973, p. 9-10) briefly mentioned the Pattiway Formation as a part of a larger succession of Cretaceous and Paleocene rocks exposed in several other areas of the Coast Ranges but restricted the name "Pattiway" to the outcrops of the southeastern Caliente Range. Sage (1973) briefly discussed the Pattiway Formation in an unpublished dissertation. A much more detailed map was compiled by Vedder and Repenning (1975) and the unit was briefly described by Vedder (1975). These reports indicated that nearby wells had drilled another 860 m of possible Pattiway or Cretaceous beds, further adding to the potential thickness.

METHODS

Paleomagnetic sampling was conducted in the spring of 2000, using simple hand tools to collect 3 oriented blocks per site. The section (Fig. 1) was measured with a Jacob's staff, following the geologic mapping of Vedder and Repenning (1975).

In the laboratory, the block samples were cored using an air-cooled drill press, or ground into cylinders using a sanding wheel. Small samples were cast into cylinders using Zircar aluminum oxide ceramic. All samples were measured on the 2G cryogenic magnetometer at the California Institute of Technology, equipped with an automatic sample changer. After measurement of NRM (natural rema-

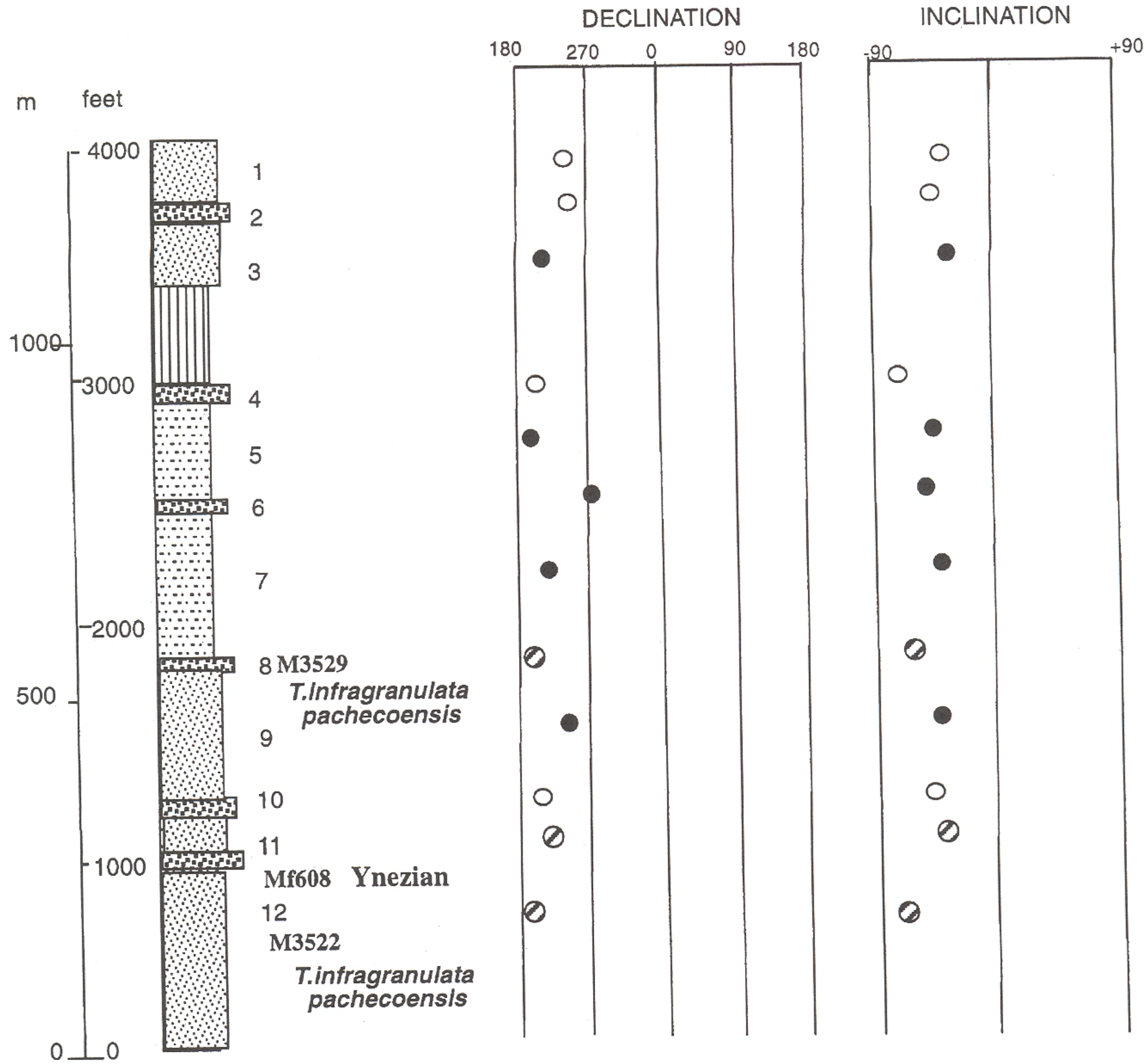


Figure 4. Magnetic stratigraphy of the Pattiway Formation. Fossil localities (M = mollusc; Mf = microfossils) correlated to section following the map of Vedder and Repenning (1975). Solid circles are Class I sites of Opdyke et al. (1977), which are statistically clustered; circles with diagonal pattern are Class II sites, which had only two samples, so no statistics could be calculated; open circles are Class III sites, which had one sample divergent.

nent magnetization), each sample was demagnetized at 25, 50, and 100 Gauss to determine the coercivity behavior and demagnetize any multi-domain grains before their remanence is baked in. All samples were then thermally demagnetized at multiple steps up to 600°C. This dehydrates any iron hydroxides, such as goethite, and also allows determination of how much magnetization remains above the Curie temperature of magnetite (580°C).

In addition to AF and thermal demagnetization of every sample, about 0.1 g of several samples were powdered and placed in epindorph tubes for rock magnetic analyses. Each powdered sample was subjected to increasing IRM (isothermal remanent magnetization), and peak IRM and ARM (anhysteretic remanent magnetization) was subjected to AF demagnetization in a modified Lowrie-Fuller test (see Pluhar et al., 1991, for further details).

RESULTS

Orthogonal demagnetization ("Zijderveld") plots of representative samples are shown in Figure 2.

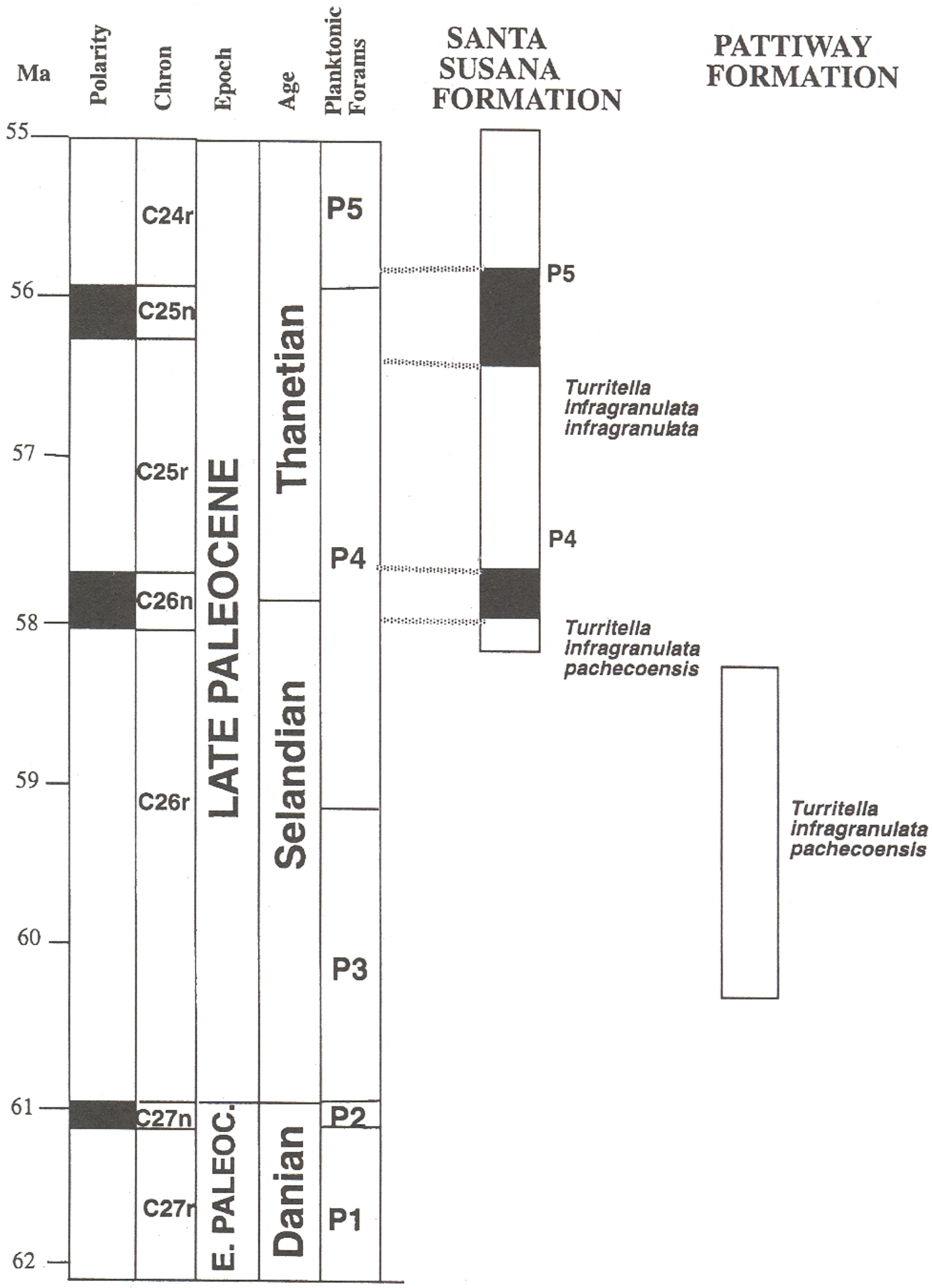
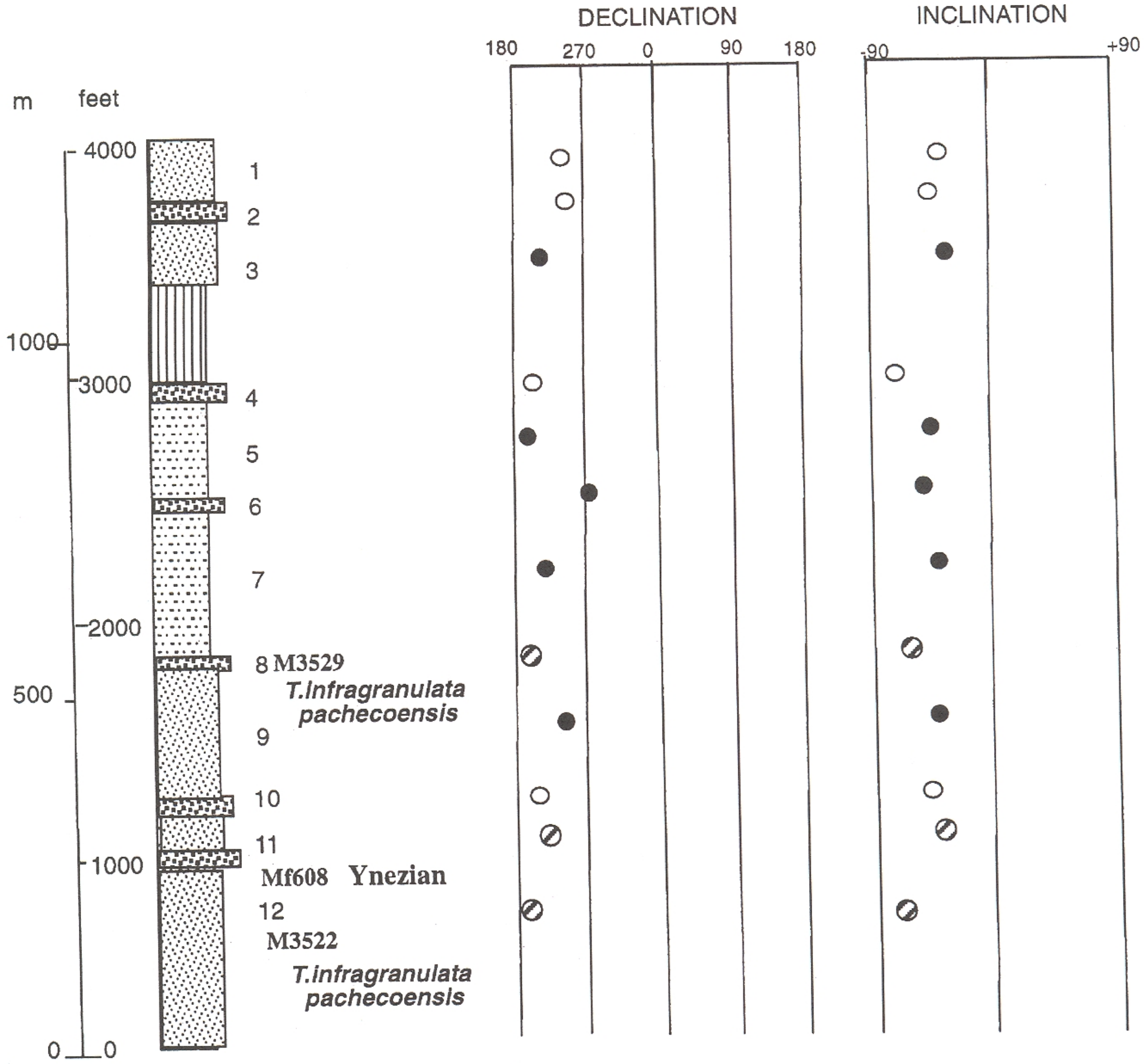


Figure 5. Correlation of the Pattiway section with the magnetobiostratigraphy of the Santa Susana Formation (after Bottjer et al., 1991), and with the time scale of Berggren et al. (1995).

Some samples (Fig. 2A, B) showed very little response to AF demagnetization, suggesting that there was significant high-coercivity remanence held in goethite or hematite. However, most of the samples lost nearly all their remanence above the Curie point of magnetite, suggesting that some of the remanence is held in magnetite with a goethite overprint. Nearly all the samples (Fig. 2A, B) showed a single component of remanence that was southwest and up (a reversed direction rotated clockwise). A few samples (Fig. 2C) showed a modern normal overprint that was removed during the first thermal demagnetization step, also suggesting that remanence is held in magnetite overprinted by goethite.

IRM acquisition studies (Fig. 3) showed that the IRM starts to plateau at 300 mT, suggesting that magnetite is a major carrier of the remanence, with a minor component of hematite or goethite. In the modified Lowrie-Fuller test, the ARM was more resistant to AF demagnetization than was the IRM, showing that the remanence is held in single-domain or pseudo-single-domain grains.

Average vectors for each sample were estimated using the least squared method of Kirschvink (1980), and statistics were calculated using the methods of Fisher (1953). The site statistics for the Pattiway



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Formation are shown in Table 1. The formational mean was D = 231.8, I = -52.6, k = 10.4, α_{95} = 14.1 (n = 12). There were no normal directions to perform a reversal test for stability, and the dips were homoclinal, preventing a fold test. Nevertheless the fact that the dip-corrected direction show a clear reversed rotated direction suggests that it is a primary or characteristic direction, and overprinting was removed.

The magnetic stratigraphy of the Pattiway section is shown in Figure 4. Sites were ranked according to the method of Opdyke et al. (1977). Class I sites (n = 5) were statistically separated from a random distribution at the 95% confidence level. Class II sites (n = 3) had one sample missing, so site statistics could not be calculated. Class III sites (n = 4) had two directions which showed a clear polarity preference, but the third direction was divergent.

DISCUSSION

Magnetic Correlation

Figure 5 shows our correlation of the Pattiway section with the magnetic polarity time scale of Berggren et al. (1995), and with the results from the Santa Susana Formation reported by Bottjer et al. (1991). Although the reversed polarity of the Pattiway Formation is not diagnostic in and of itself, the results from the Santa Susana Formation help constrain our interpretations. According to Heitman (1983), these same strata yield Zone P4 planktonic microfossils, so Bottjer et al. (1991) correlated the lower part of the Santa Susana Formation with Chron C25r-C25n and uppermost C26r (Fig. 6). This pattern is also seen in the Locatelli Formation of the Santa Cruz Mountains, which yields a "Martinez Stage" *Turritella infragranulata pachecoensis* fauna and Zone P4 planktonic microfossils, and is also entirely of reversed polarity (Prothero and Lopez, this volume), and in the Silverado Formation of the Santa Ana Mountains of Orange County, which yields a "Martinez" stage *Turritella infragranulata pachecoensis* fauna (Prothero and Lopez, this volume). Thus, the correlation of the Pattiway Formation with Chron C26r (58.0-60.9 Ma) is the most reasonable interpretation, given our data constraints.

Tectonic rotations and translations

The formational mean inclination value is 52.5 ± 14.1°; its modern latitude of 35° suggests an inclination value of 54.5°. Thus, the paleolatitude is not significantly different from the present-day latitude, suggesting relatively little northward translation of this terrane since the Paleocene. However, the error estimates are so large that up to 14° of northward translation cannot be ruled out.

Our formational mean declination of 51.8 ± 14.1° suggests a clockwise tectonic rotation of about 60° (after comparison to the Paleocene stable cratonic pole of Diehl et al., 1983, and correction of the error estimate according to the method of Demarest, 1983). This is consistent with the large clockwise tectonic rotations seen elsewhere in the Transverse Ranges, but the Pattiway Formation is located on a tectonic block that is north of the Big Pine fault and supposedly unrotated (Hornafius et al., 1986; Luyendyk and Hornafius, 1987; Luyendyk, 1991). Yet Ellis et al. (1993) showed clockwise rotation even in the Miocene-Pleistocene rocks in the region, and Prothero and Hoffman (this volume) also reported a clockwise tectonic rotation of 60° from the lower Miocene Soda Lake Shale Member of the Caliente Range, just a few kilometers north of the Pattiway Formation. This suggests that a large pre-middle Miocene tectonic rotation is widespread throughout the region, and that the Caliente Range apparently took part in the clockwise rotation during the Miocene that has already been reported from the Caliente Formation in the Cuyama Badlands (Prothero et al., in press).

CONCLUSION

Paleomagnetic analysis of the Pattiway Formation in the southern Caliente Range, California, shows that it is entirely of reversed polarity. Based on the distinctive molluscan fauna correlated with Zone P4 planktonic microfossils in the Santa Susana Formation of Ventura County, we correlate this reversed magnetozone with Chron C26r (58.0-60.9 Ma). The Silverado Formation shows no significant evidence of northward translation, but a significant clockwise rotation of about 60°. This latter result compares favorably with others in the region, and suggests that it has undergone the same clockwise rotations found in the Transverse Ranges to the south. This is not consistent with tectonic models which place the Caliente Range on a block north of the rotated tract, which has only slid smoothly northward without rotation.

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TABLE 1—Fisher statistics of sites from the Pattiway Formation. Site numbers as in Figure 4. N: number of samples per site; D, I: declination, inclination; k, α_{95}, precision parameters.

Site	N	D	I	k	α_{95}
1	3	251.2	-29.8	1.4	180.0
2	3	259.8	-41.7	3.4	80.7
3	3	211.1	-34.7	12.6	36.3
4	3	218.1	-78.7	5.1	61.3
5	3	203.0	-46.4	5.7	57.2
6	3	275.6	-51.8	5.8	56.6
7	3	239.1	-36.4	27.9	23.8
8	1	184.0	-65.7	—	—
9	3	260.8	-40.4	11.8	37.6
10	3	199.3	-45.1	3.2	85.7
11	2	232.7	-39.3	21.5	56.5
12	2	156.0	-78.2	70.8	30.1