Magnetostratigraphy of the Kavaalani section (southwestern Turkey): Consequence for the origin of the Antalya calcareous nappes (Turkey) and for the Norian (Late Triassic) magnetic polarity timescale

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Abstract. A magnetostratigraphic study of the Kavaalani section of uppermost Carnian to Upper Norian age, located in the Antalya Calcareous Nappes (southwestern Turkey), reveals nineteen polarity intervals. This pattern correlates very well with two other polarity sequences obtained from the same nappe system (Bolücektasi Tepe and Kavur Tepe) if these sections were deposited in the same (northern) hemisphere. This new interpretation changes our previous conclusions regarding the southern hemisphere origin of the magnetic remanence of the Kavur Tepe section. The paleomagnetic data obtained from the Kavur Tepe and the Kavaalani sections therefore reflect large (~180°) internal rotations within the Antalya nappes. These nappes were likely formed close to the northern tip of the Arabian promontory. We propose a revised yet still preliminary version of the Norian magnetic polarity sequence.

1. Introduction

The definition of the Triassic magnetic polarity timescale is an active research field, with the recent acquisition of numerous magnetostratigraphic data [e.g., *Gallet et al.*, 1992; *Kent et al.*, 1995; *Molina-Garza et al.*, 1996; *Muttoni et al.*, 1997]. In previous studies, *Gallet et al.* [1992, 1993, 1994, 1996] proposed magnetic polarity sequences for the Carnian and the Norian (Late Triassic) from several marine sedimentary sections of the Tethyan realm. The composite sequences were mainly constructed from data of the Antalya Calcareous Nappes (ACN) in southwestern Turkey [e.g., *Marcoux*, 1979, 1987]. The Bolücektasi Tepe (BT) section was clearly deposited in the northern hemisphere [*Gallet et al.*, 1992, 1994], while the Kavur Tepe section (KT) surprisingly exhibited a paleomagnetic direction that could be interpreted either as reflecting a deposition in the southern hemisphere or a large rotation of nearly 180° [*Gallet et al.*, 1993]. Magnetostratigraphic correlation between the two latter sections, and another Norian section sampled from the Northern Calcareous Alps (Scheiblkogel) supported the southern origin of the Kavur Tepe section [*Gallet et al.*, 1993, 1996]. However, this result contradicted the geologic interpretation [e.g., *Marcoux*, 1987; *Marcoux et al.*, 1989] and additional work was necessary to decipher the origin of the ACN. We present in this paper magnetostratigraphic data from the Kavaalani section (KV) located in the vicinity of the Bolücektasi Tepe section.

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2. Description of the Kavaalani section

The Kavaalani section, as Bolücektasi Tepe, belongs to the Barkirli Dag unit of the ACN in the western Taurides (Lat.. 36°17'N, Long.: 30°20'E ; *Marcoux* [1987]). It is located on top of a small summit (~2000 m of altitude), 3 km to the south of the Bakirli Dag peak and about 25 km to the north of BT. The sampled section has a thickness of about 55 meters and consists of light pink and whitish pelagic sediments in Hallstatt facies gently dipping (~30°) to the north-east.

The biochronology of the Kavaalani section is mainly based on conodonts. More than 50 conodont samples allow recognition of the same conodont zonation used in our previous studies (Figure 1). All binomal zonal guide forms have a long and generally accepted taxonomy, and their chronostratigraphic correlation potential is well-established [*Kozur*, 1972; 1990; *Krystyn*, 1980; *Orchard*, 1991]. They indicate an age from the latemost Carnian (Tuvalian 3 zone) to the beginning of the late Norian (Sevatian 1 zone; Figure 1). Rare but biostratigraphically diagnostic megafossils

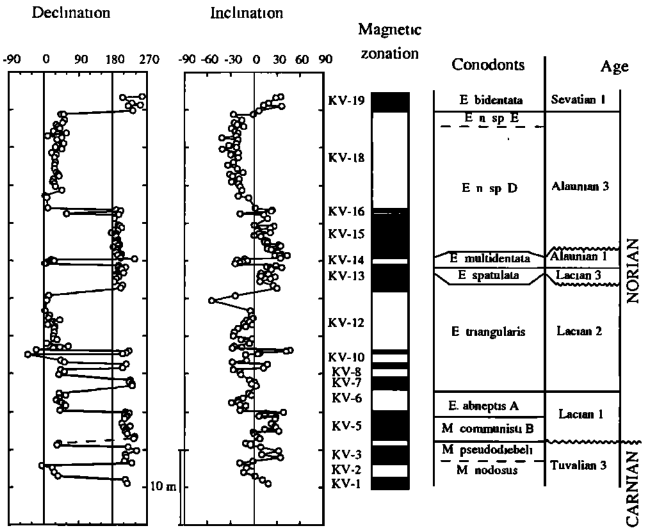

Figure 1. Magnetostratigraphy of the Kavaalani section. The magnetic zonation assumes that the section was deposited in the northern hemisphere.

consist of ammonoids (A) and short-lived pelagic bivalves (H). This includes *Halobia austriaca* (H) at 0.1 m, *Placites placodes* (A) at 1.0 m, *Perihalobia styriaca* (H) at 4.5 m and *Halobia halorica* (H), and *Cyrtopleurites* sp. (A) at 34.2 m above the base of the Norian. The halobia species are of special interest as they establish precise correlations within certain time intervals between BT and KV (basal Lower Norian), as well as between KV and KT (basal Middle Norian). Of the conodont species cited in open nomenclature, *Epigondolella* n.sp. D is morphologically very similar to *E. slovakensis* and *Epigondolella* n. sp. E to *Parvigondolella? vrielyncki*. (Figure 1). Their ranges have been dated in ammonoid controlled sections of Timor [*Tatzreiter*, 1981]. Within the lower part of the section, *Epigondolella abneptis* A (Lower Norian) is a morphological counterpart of *E. quadrata* [*Orchard*, 1991] and *Metapolygnatus pseudodiebeli* (Upper Carnian; *Kozur* [1972]) is here regarded as independent species and guide for a time interval previously included in the "Upper Nodosus range zone" by *Gallet et al.* [1994].

The sedimentary record of the Kavaalani section is rather uncomplete. Some time intervals are extremely thin, the Lacian 3 zone has a thickness of 0.5 m and the Alaunian 1 zone a thickness of 1.5 m. At least three sedimentary breaks are indicated by hard grounds and/or relief-toped beds with erosional surfaces. Two levels mark the Carnian-Norian and the Lacian 2 to 3 boundaries. The third corresponds to the absence of the entire Alaunian 2 zone. The discontinuity at the Carnian-Norian boundary may explain the absence of the top-Carnian M. communisti A zone.

Paleogeographically, the Kavaalani and the Kavur Tepe sections were deposited in the same distal basinal setting. Reduced sediment accumulation and/or larger stratigraphic gaps during the Middle Norian observed in both sections seem to be a widespread feature of Hallstatt type sequences of the Tethys [e.g., *Krystyn et al.*, 1971; *Tatzreiter*, 1981]. The higher sedimentation rate in BT is likely the result of a special paleogeographic position close to the slope of a carbonate platform, with a higher amount of carbonate sediment shedding from the platform.

3. Paleomagnetic results

About 200 samples were collected in 1996 through the section. They were analysed in the shielded paleomagnetic laboratory at the Institut de Physique du Globe de Paris.

The paleomagnetic properties of the Kavaalani section are very similar to those previously observed from the Kavur Tepe section. Thermal demagnetizations isolate two magnetization components (Figure 2). The first one is observed in the low temperature range, between 120°C and 200°C (LT component), and has in geographic coordinate system the direction of the present-day geomagnetic field at the site. A high temperature (HT) component, which unblocks toward the origin of orthogonal vector diagrams, is then isolated up to 560°C-580°C. It is carried by magnetite, and yields dual-polarity directions (Figure 3).

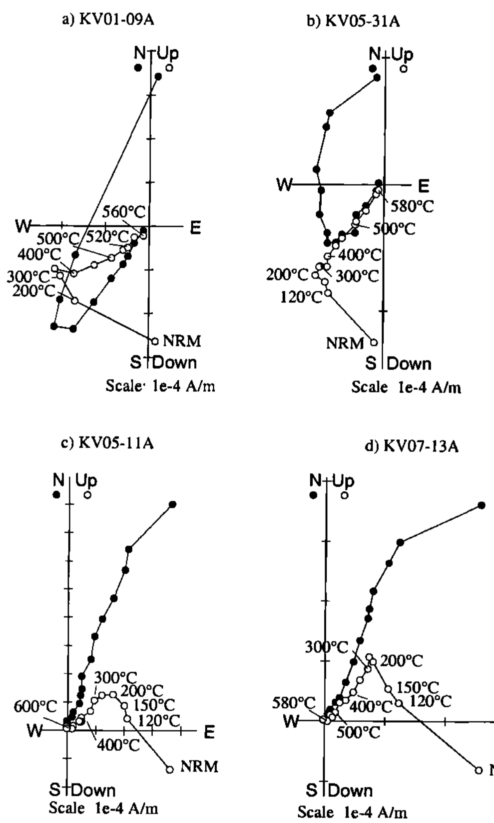

Figure 2. Orthogonal vector diagrams in stratigraphic coordinates of progressive thermal demagnetization of samples from the Kavaalani section.

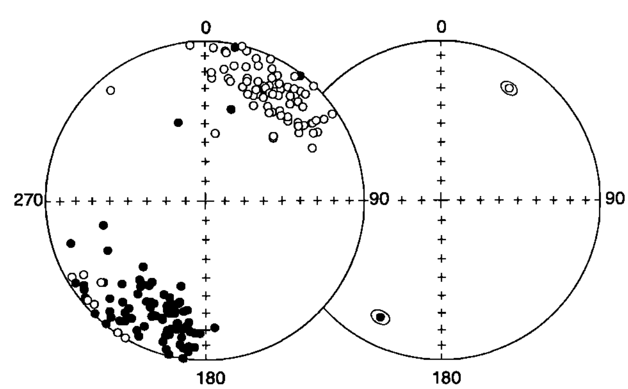

Figure 3. Equal area projection in stratigraphic coordinates of directions isolated for the high temperature component from the Kavaalani section.

Table 1. Mean directions obtained for the high temperature component from the Kavaalani section.

Component		N samp.	Decl. before tilt correction	Incl. before tilt correction	Decl. after tilt correction	Incl. after tilt correction	a_{95}	K
HT Comp.	Normal	85	208.7°	-11.7°	207.6°	18 5°	4.0°	15 4
	Reversed	78	32 8°	9.5°	31.5°	-18.8°	3.7°	19 9
	General	163	210.7°	-10.6°	209.5°	18.6°	2 7°	17.2
VGP		Lat -36 4°	Long.. -6.8°		dp/dm: 1.5°/2.8°		Paleolat: 9.6°	

The directions obtained for the HT component yield a positive reversal test (Table 1; γ=3.7° for γ_c=5.5°; *McFadden and McElhinny* [1990]). After bedding correction, the mean direction is of south-southwest declination and positive inclination. The similar bedding attitude of BT and KV does not allow a fold test between the two sections. As for Kavur Tepe, the paleomagnetic direction found in KV may either reflect a large internal tectonic rotation within the Antalya nappes (by comparison with the direction found in BT) or deposition in the southern hemisphere. However, the very close proximity of KV with BT and its identical structural tectonic position within the ACN strongly suggest that these two sections have experienced large relative rotations. This is further confirmed by the paleolatitude obtained from Kavaalani (9.6° [8.1°-11.0°]) which is almost identical to the value calculated for the upper part of the BT section (10.4° [9.4°-11.3°]; *Gallet et al.* [1992]). We note that the northern hemisphere origin of the Bolücektasi Tepe section was demonstrated by a clear magnetostratigraphic correlation between its Lower Carnian part and the Mayerling section from the Northern Calcareous Alps [*Gallet et al.*, 1994].

4. Magnetostratigraphy of Kavaalani and its comparison with previous data

The HT component from KV defines a magnetic zonation of nineteen intervals (Figures 1 and 4). Among these intervals, only one is defined by a single sample (KV-16), and three by two samples collected at different stratigraphic levels (KV-04, KV-09 and KV-17). The interval KV-07 is essentially defined by declinations because the corresponding inclinations are very low and are probably biased by the LT component (Figure 1).

The Kavaalani and the Kavur Tepe sections show similar magnetic polarity signatures for the upper part of the Lacian 2 zone, the Lacian 3 zone, and a large part of the Alaunian 3 zone, if they were deposited in the same hemisphere (Figure 4). The comparison is less satisfactory for the Alaunian 1 zone, but its thickness is reduced to only 1.5 m in KV and is uncomplete in KT. The comparison between KV and BT is also satisfactory for the Lacian 1 and the Lacian 2 zones, although the middle part of the Lacian 2 zone present in BT is perturbed by faulting, which may explain the occurrence at this stratigraphic level of short and/or poorly defined magnetic polarity intervals (Figure 4).

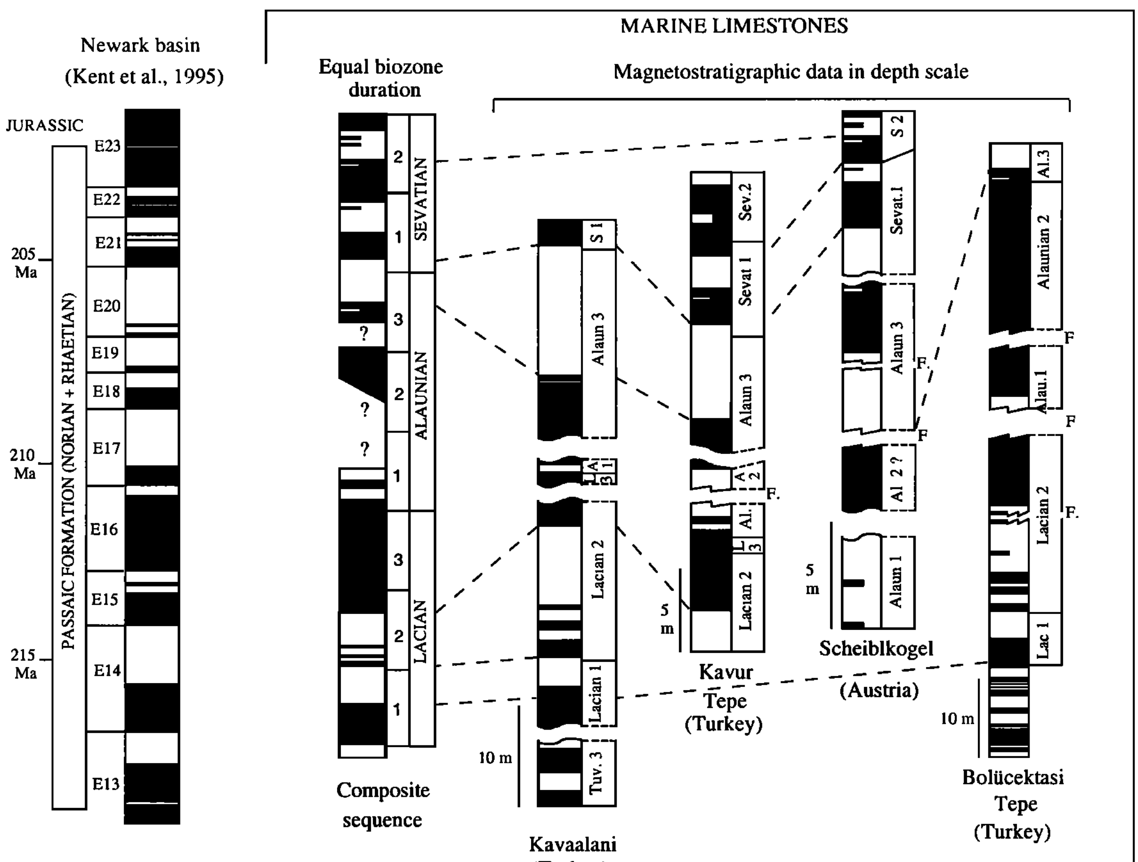

Figure 4. Comparison among magnetostratigraphic sequences from Kavaalani (this study), Bolücektasi Tepe [*Gallet et al.*, 1992], Kavur Tepe [*Gallet et al.*, 1993] and Scheiblkogel [*Gallet et al.*, 1996]. A composite Norian magnetic polarity sequence is constructed considering an equal duration for the biozones.

Despite some stratigraphic complexities in the studied sections (faulting and/or sedimentation gaps), the Norian magnetostratigraphic data obtained from the ACN are consistent. The magnetostratigraphy of Kavaalani provides an important confirmation of the hemisphere of deposition of the Kavur Tepe section, and yields a solution opposite to the one we previously asserted. Our new result notably simplifies the origin of the strata of the Antalya nappes, which were likely deposited close to the northern tip of the Arabian promontory.

A composite Norian magnetic polarity sequence is shown in Figure 4 considering an equal duration for the biozones. This sequence will be modified when data on the duration of the Norian biozones are available. The Lower Norian (Lacian 1 to Lacian 3 zones) is better represented in KT and KV. Because of the low sedimentation rate, we cannot exclude the possibility of a more complex reversal sequence during the Lacian 3 than a single normal polarity interval. The Middle Norian magnetic polarity sequence is more problematic. No section yields a sequence over a complete biozone. The Alaunian 1 zone is either very reduced or uncomplete. KT probably provides the most accurate reversal sequence for the lower part of this biozone. The Alaunian 2 zone, which was considered for establishing the original correlation between BT and KT, is in fact highly uncomplete in both sections. The lower part of this zone is missing in BT (and in Scheiblkogel) due to faulting; its upper part is strongly reduced in KT. The data therefore only indicate the occurrence of a normal polarity interval during the upper part of this biozone and of a reversed interval probably during its lower part. Furthermore, new observations of the Scheiblkogel section indicate that its Alaunian 3 zone is structurally more complicated than previously thought, which complicates the use of this part of the section. The normal-reverse sequence observed in KV and KT can be confidently considered for the upper part of this biozone, but its correlation with the polarity reversal observed in the topmost part of BT is not confirmed. The Upper Norian magnetostratigraphy is established from the Kavur Tepe and the Scheiblkogel sections. Additional results are required to confirm the occurrence of some polarity intervals during the Sevatian 2 zone which are poorly defined in Scheiblkogel.

The revised version of the composite Norian magnetostratigraphy must be supported by other data from more complete marine sections from the Tethys. In particular, the low sedimentation rate in our sections may preclude the detection of short magnetic polarity intervals. The Middle Norian part of the sequence is uncomplete, and a convincing correlation with polarity data from the Newark basin is still lacking (Figure 4; *Kent et al.* [1995]).

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