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# Upper Cretaceous and Palaeogene magnetic stratigraphy and biostratigraphy from the Venetian (Southern) Alps

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Four sections of Upper Cretaceous/Eocene pelagic limestones from the Belluno basin of the Venetian Alps (Italy) yield well-defined magnetic stratigraphies. The correlation of magnetozones with nannofossil and foraminiferal zonations generally agrees well with that obtained from the type-section at Gubbio [1]. The magnetostratigraphy supplements the palaeontology as a means of stratigraphic correlation. Variations in sedimentation rate and in the duration of hiatuses are clearly documented for the four different locations in the basin.

## 1. Introduction

During the Mesozoic, the Southern Alps were part of the southern continental margin of the Tethyan ocean [2–4]. The morphology of this part of the continental margin comprised an external carbonate platform (Friuli platform) and two continental margin basins (Belluno and Lombardy basins) separated by an intervening chain of seamounts known as the Trento plateau (Fig. 1). Deformation affected this part of the margin from Early Tertiary. The crustal shortening was generally less severe than elsewhere, and the present geography of platform and basin sedimentation reflects the palaeogeography of the margin during the Mesozoic (Fig. 1).

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The Belluno basin developed between the Friuli platform and the Trento plateau and these basinal sediments outcrop in an area known as the Venetian Alps. We have collected oriented samples from four Upper Cretaceous/Early Tertiary sections in the Belluno basin in order to: (a) correlate these lithologically uniform sections using both the biostratigraphy and the magnetostratigraphy; (b) estimate the length of time represented by hardgrounds which occur in each section; (c) correlate the polarity zones with foraminiferal and nannofossil zones, and compare this correlation with the magnetostratigraphic type-section at Gubbio [1].

## 2. General stratigraphy

The Upper Cretaceous, Paleocene and Lower Eocene are generally represented in the Venetian Alps by the pelagic Scaglia rossa formation which

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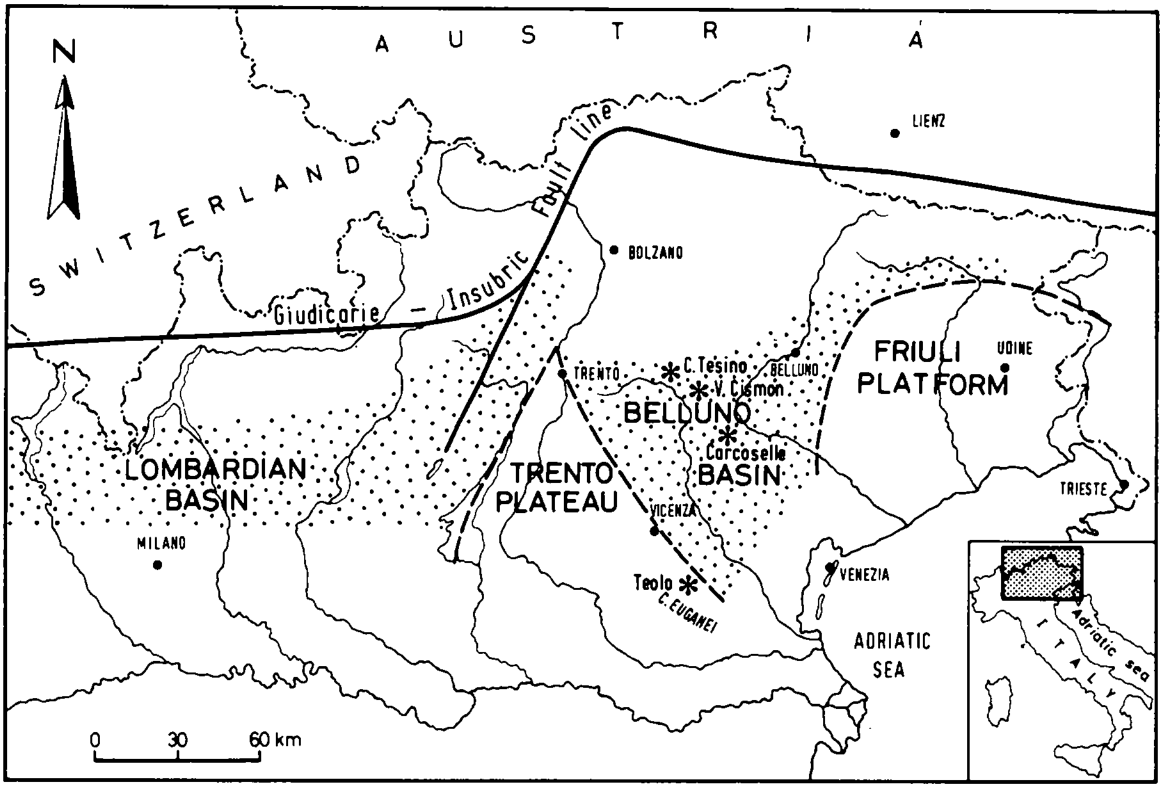



Fig. 1. The present configuration of Late Cretaceous palaeogeographic zones in the Southern Alps; basins are stippled. The locations of the four sampled sections in the Belluno basin are indicated (see Fig. 2 for more precise location).

is a pink to red, well-bedded, limestone to marly limestone rich in calcareous nannoplankton and planktic foraminifera. Red-brown nodular cherts occur in the pre-Campanian interval and shaly interbeds are present from Upper Campanian.

The upper part of the Scaglia rossa is characterised by stratigraphic gaps, generally marked by abrupt changes in lithology and sometimes by hard-grounds with ferruginous-phosphatic crusts. The stratigraphic lacunae may range from part of one foraminiferal zone to several zones. A continuous sedimentary sequence cannot be found in any Scaglia rossa section in the Venetian area [5]. The most condensed sequences are found on the Trento plateau which was predominantly a non-depositional area during the Campanian/Maastrichtian and Paleocene. Thicker and more complete, though usually not continuous sequences are found in the neighbouring Belluno basin. One of the sections investigated here, the Teolo section, is located at the southeastern border of the Trento plateau. The others, those at Carcoselle, Castel Tesino and Cismon, are situated in the Belluno basin (Figs. 1 and 2).

The biostratigraphic subdivision of the Upper Cretaceous through Lower Eocene pelagic sequence is principally based on planktic foraminifera. The species were identified from thin sections of the same beds sampled for palaeomagnetism, and from washed residues from the upper more marly part of the succession (from Upper Campanian onwards). The planktic foraminiferal biostratigraphy of the Santonian through Maastrichtian part of the sections has already been published by Massari and Medizza [5]. In the present paper, however, a more detailed zonation for the Maastrichtian has been used. The zonal scheme is the same as the one employed by

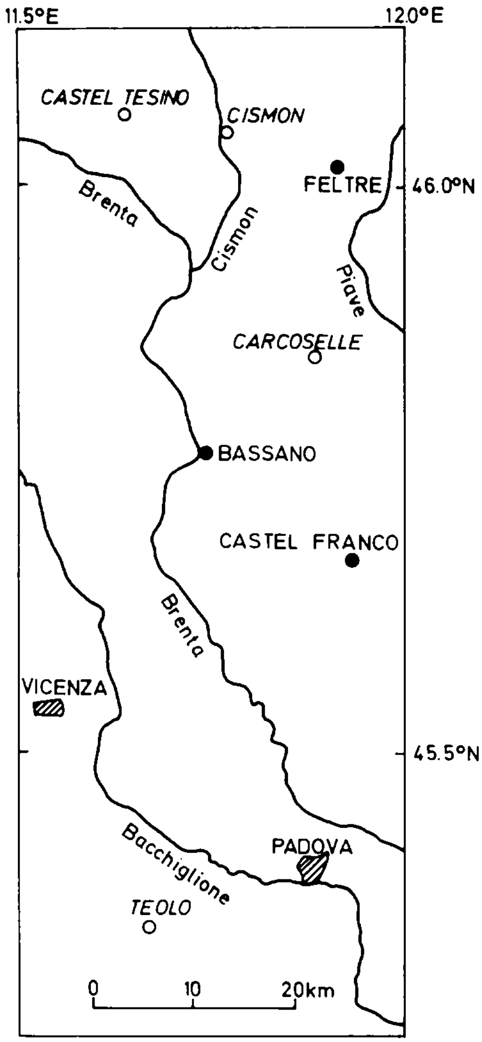



Fig. 2. The location of sampled sections (Castel Tesino, Carcoselle, Teolo and Cismon) with respect to the main towns and rivers.

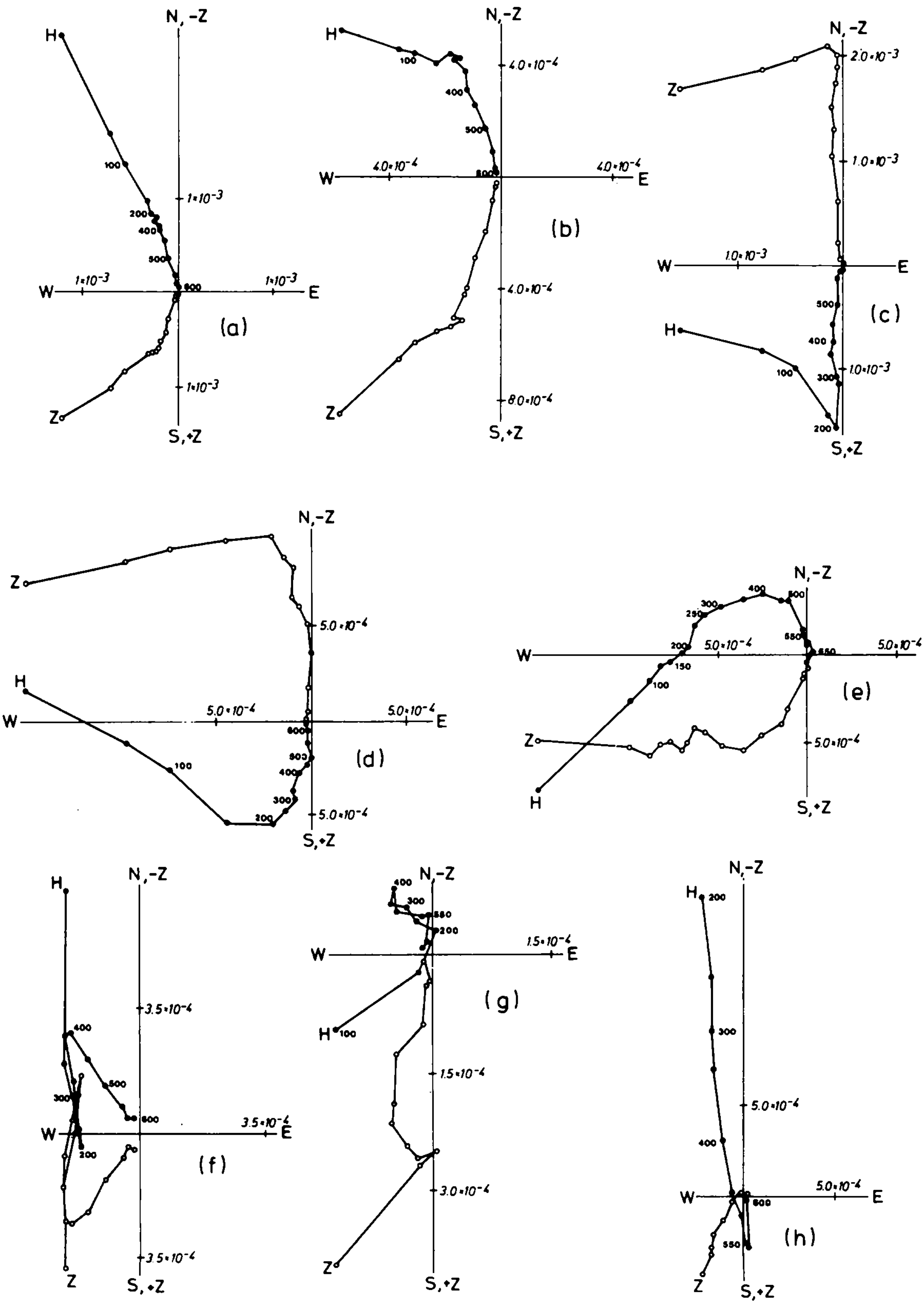
Premoli-Silva [6] for the Umbrian Gubbio section, which has been proposed as the magnetostratigraphic type section for the Upper Cretaceous and Paleocene [1].

From the Upper Campanian onwards, the samples used for the study of foraminifera were also investigated for their nannoplankton content. The poor preservation of the nannofossil assemblages does not allow a detailed zonation for the Cretaceous. Two total range zones—the *Quadrum trifidum* Zone [7] and the *Micula murus* Zone [8]—were recognized. The interval between these zones, which is usually differentiated on the basis of the occurrence of *Lithraphidites quadratus*, was not zoned because this species has not, up to now, been recognized in our sections. In this interval other palaeontological events, such as the last occurrence of *Reinhardtites levis*, were recognized. The Standard Zonation of Martini [9] was used for the Paleocene and the Lower Eocene.

## 3. Magnetic properties of southern Alpine Scaglia rossa

The magnetic properties of the Southern Alpine Scaglia rossa have not previously been studied in detail, although the same formation has been extensively studied further south in Umbria. The Cretaceous Scaglia rossa from Umbria has a natural remanent magnetization (NRM) dominated by magnetite with only minor contribution from pigmentary haematite [10,11]. However in the Paleocene of Umbria, the deeper red colour of the Scaglia rossa reflects enhanced contribution of haematite to the NRM. The haematite probably grew from a goethitic precursor during early diagenesis [12–14]. There is evidence from Umbrian Scaglia that although haematite growth continued for times of the order of $10^5$ years, the growth began very shortly after deposition, in the upper few centimeters of soft sediment [14]. If we can assume that those haematite grains which began growing first attained the largest grain size, then the highest blocking temperature haematite magnetization component can be correlated with the palaeontological age of the sediment.

Thermal demagnetization proved to be an effective procedure for isolating the characteristic magnetization of the Southern Alpine Scaglia rossa. Generally, the samples exhibited univectorial decay above demagnetization temperatures of 200°C (Fig. 3a–d) and the choice of characteristic magnetization direction was unambiguous. However, samples taken from just below reversal boundaries show the presence of haematite which grew through its critical volume after the polarity change. In such samples (Fig. 3f–h) we see a magnetization



(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
N, -Z
S, +Z
W
E
H
Z
1×10⁻³
4.0×10⁻⁴
8.0×10⁻⁴
1.0×10⁻³
2.0×10⁻³
5.0×10⁻⁴
3.5×10⁻⁴
1.5×10⁻⁴
3.0×10⁻⁴

component due to later haematite growth (finer-grained, lower blocking temperature) which is antiparallel to the magnetization components due to earlier formed (coarser-grained, higher blocking temperature) haematite.

Most of the samples were thermally demagnetized at 300°, 400° and 450°C and the magnetization polarity was generally unambiguous. However, in some Palaeogene samples from very close to reversal boundaries (Fig. 3h), the polarity changed at temperatures above 450°C.

## 4. The Castel Tesino section

An Upper Cretaceous to Eocene sequence crops out approximately 3 km northeast of the village of Castel Tesino (Fig. 2), along a trail leading off the road from Passo del Brocon to Magri. A Coniacian to Lower Paleocene interval has been sampled for palaeomagnetism. The virtual geomagnetic polar (VGP) latitude given by each sample is used as a measure of polarity, and is plotted against stratigraphic position (Fig. 4). VGP latitudes are the latitudes relative to the palaeoequator and palaeomagnetic pole. The palaeoequator and the palaeomagnetic pole are given by the mean palaeomagnetic direction for the entire section. The polarity zones (magnetozones) are correlated with those recognized in the magnetostratigraphic type section at Gubbio [1] and are labelled accordingly.

Nine foraminiferal zones, three nannofossil zones and six magnetozones are recognized (Fig. 4). The continuity of the sequence is interrupted by a stratigraphic gap in the Upper Campanian to Lower Maastrichtian interval. The lower part of the Campanian *Globotruncana elevata* Zone is topped by a hard-ground. Sediments immediately above it contain middle Maastrichtian foraminiferal assemblages of the *Globotruncana gansseri* Zone and nannofossils belonging to the lower part of the unzoned interval between the *Quadrum trifidum* Zone and *Micula murus* Zone, which is characterised by the occurrence of *Reinhardtites levis*. Two foraminiferal zones, one nannofossil zone and polarity zones B +, C − and D + are missing at this discontinuity.

Sedimentation at the Cretaceous/Tertiary boundary is more or less continuous. The *Globogerina eugubina* foraminiferal zone is recognized, as are nannofossil zones NP 1 and NP 2. The Cretaceous/Tertiary boundary is clearly *within* polarity zone G −. In most Scaglia sections the Tertiary part of the zone G − is missing.

## 5. The Carcoselle section

A thick pelagic sedimentary sequence ranging in age from the Late Cretaceous to the Middle Eocene is well exposed in the Carcoselle quarry (Fig. 2). This quarry is located near the village of Possagno, between Bassano (del Grappa) to the west and the Piave river to the east, and some 50 km north of Padova. The uppermost part of the Biancone, the Scaglia rossa, the Scaglia variegata and the Scaglia cinerea crop out here. The sequence exposed in the Carcoselle quarry is the most complete of those investigated in this paper. The biostratigraphy of the Tertiary part of the section has been established by a team of micropaleontologists [15], and the Cretaceous/Tertiary boundary was described in detail by Premoli-Silva and Luterbacher [16].

The uppermost Biancone and the Scaglia rossa were continuously sampled except for a covered interval between these two formations. Two foraminiferal zones in the uppermost Biancone of Cenomanian age (Fig. 5), and nine in the Conia-

Fig. 3. Orthogonal projections of the end points of magnetization vectors during progressive thermal demagnetization of six Cretaceous samples from Castel Tesino (a, b, d), Cismon (c), Carcoselle (e) and Teolo (f), and two Paleocene samples from Carcoselle (g) and Cismon (h). Open circles are the projections of the directions in the vertical plane with respect to horizontal and vertical ($Z$) axes. Closed circles are the projections of the directions in the horizontal plane with respect to N (north), S, E and W. The axes are graduated for magnetization intensity in A/m with zero intensity at the origin of the plots. The demagnetization temperatures associated with certain points are given for the horizontal projection. The temperatures associated with other points can be interpolated. The demagnetization steps were 75°, 100°C, then 50° steps (partly 25° steps in (e)) to 550° and then 575°, 600° and occasionally a 650° step. The initial point on the plots is the NRM value except for (g) and (h) where the first points represent the 100° and 200°C steps respectively.

cian through Maastrichtian part of the Scaglia rossa are recognized (Fig. 6). The zonal sequence from Coniacian to the top of the Cretaceous is complete in spite of the occurrence of three minor stratigraphic gaps marked by hard-grounds. The first gap falls within the *Globotruncana elevata* Zone and includes the middle part of this zone. Polarity zone A − occurs below the hard-ground and B + occurs above it (Fig. 6). The second gap is situated at the boundary between the *Globotruncana tricarinata* and the *Globotruncana gansseri* Zones. Polarity sub-zone D2 − coincides with the hiatus and is not observed in this section. The third gap is situated between the *Globotruncana*

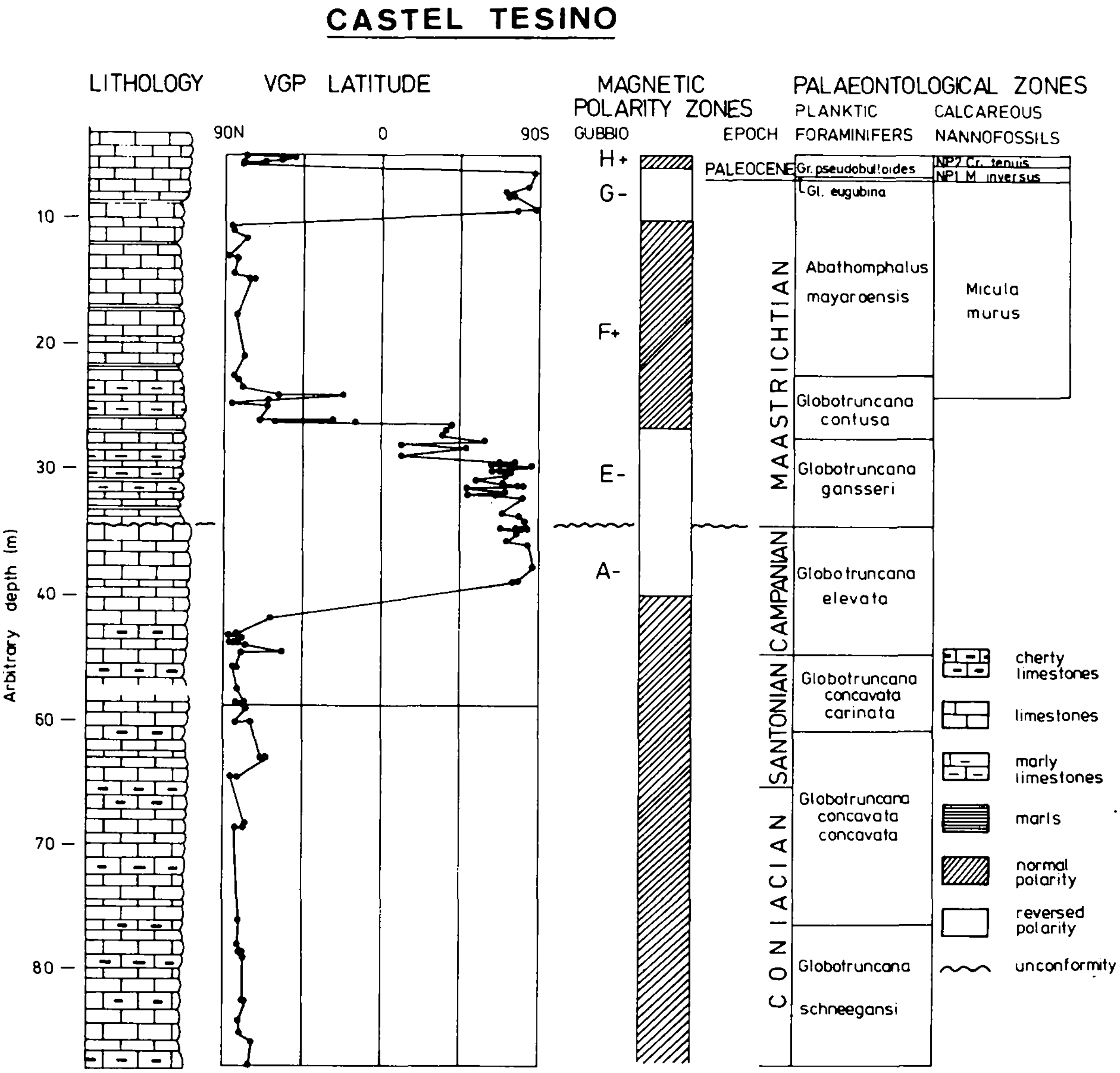



Fig. 4. The lithology, VGP latitudes, polarity zones and palaeontological zones found at Castel Tesino. The polarity zones are correlated with, and labelled according to the nomenclature for the magnetostratigraphic type-section at Gubbio [1,18]. There is a gap between 47 and 58 m where lack of exposure precludes sampling.

*contusa* Zone and the *Abathomphalus mayaroensis* Zone. Both of these zones, as well as polarity zone F +, are partially absent. No nannofossil zones are missing due to these three stratigraphic gaps.

A thin layer (1.5 cm) of dark red-brown argillaceous marls immediately overlying the Cretaceous Scaglia and containing agglutinating foraminifera and fish teeth [16] marks the Cretaceous/Tertiary boundary. The base of the Tertiary part of the section consists of irregularly thin bedded reddish

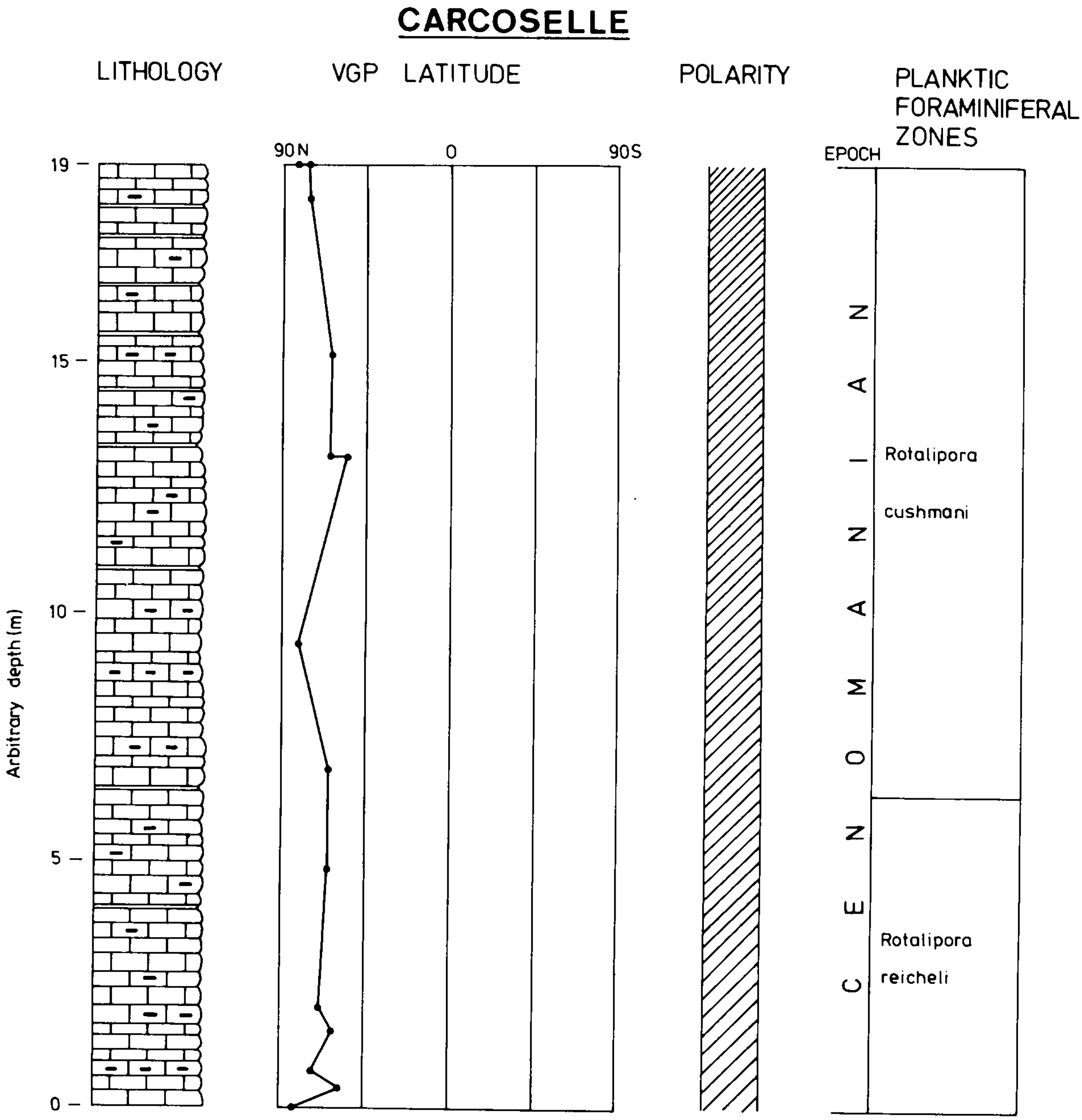



Fig. 5. The stratigraphy for the Cenomanian section at Carcoselle (key as in Fig. 4).

brown marly limestones which contain foraminifera belonging to the middle-upper part of the *Globorotalia pseudobulloides* Zone and nannofossils of the NP 2-*Cruciplacolithus tenuis* Zone. The lowermost Tertiary including the Tertiary part of polarity zone G − is therefore missing. A stratigraphic gap is also recognizable within the Paleocene. In fact, Lower Paleocene sediments belonging to the *Globorotalia pseudobulloides* and NP 3-*Chiasmolithus danicus* Zones are directly overlain by Upper Paleocene beds of the *Globorotalia pseudomenardii* and NP 8-*Heliolithus riedeli* Zones. Several foraminiferal and nannofossil zones of the middle part of the Paleocene are missing due to this gap as are polarity zones J +, K −, L + and M −.

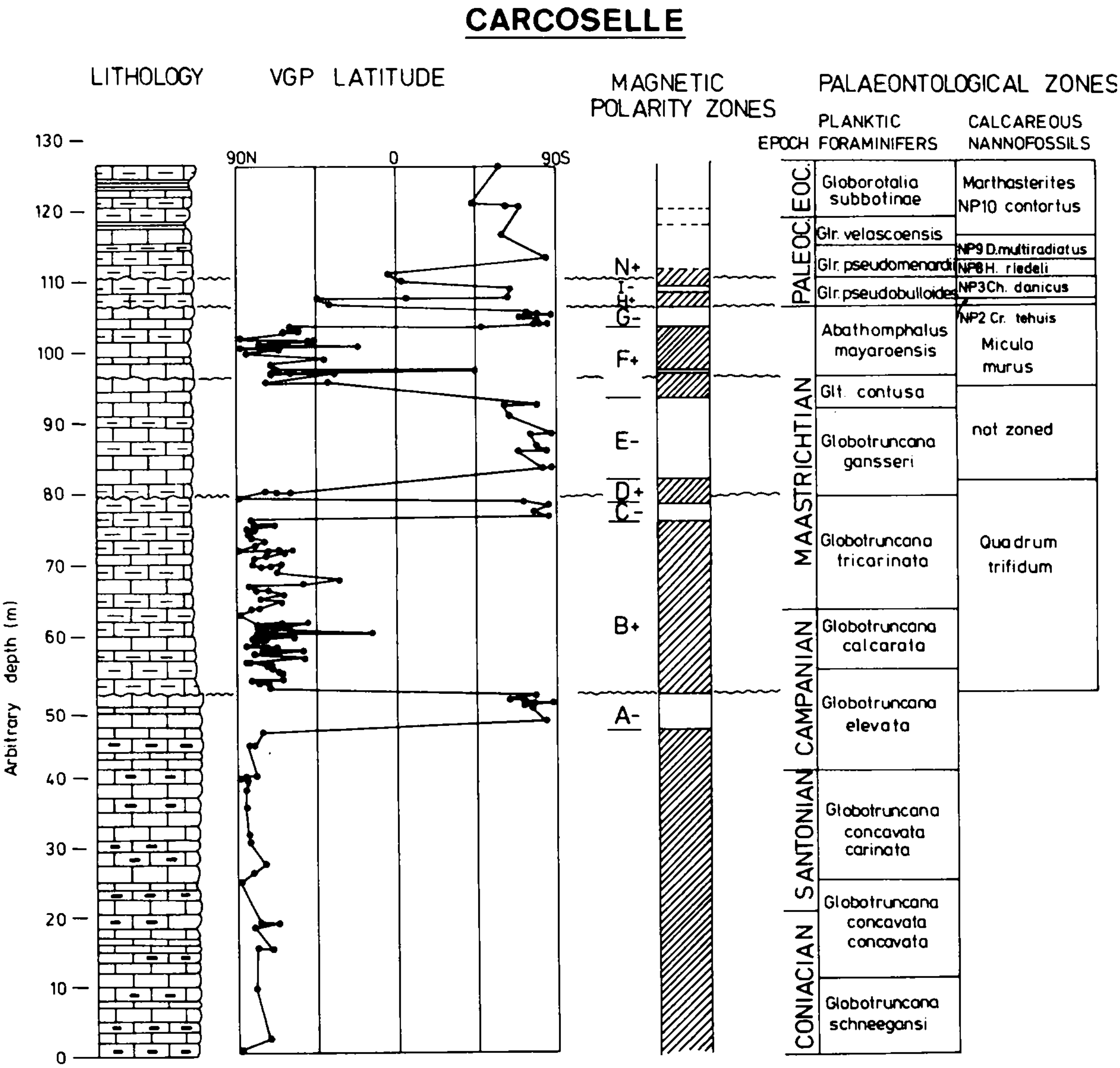



Fig. 6. The stratigraphy for the Coniacian to Eocene section at Carcoselle (key as in Fig. 4).

## 6. The Teolo section

The section is located along the road leading from Villa di Teolo to Teolo (Fig. 2) in the northern Euganean Hills. The interval sampled for palaeomagnetism ranges in age from Santonian through Maastrichtian and corresponds to the upper part of the Scaglia rossa. Three foraminiferal zones were recognized in this interval (Fig. 7). The Campanian *Globotruncana elevata* Zone is directly

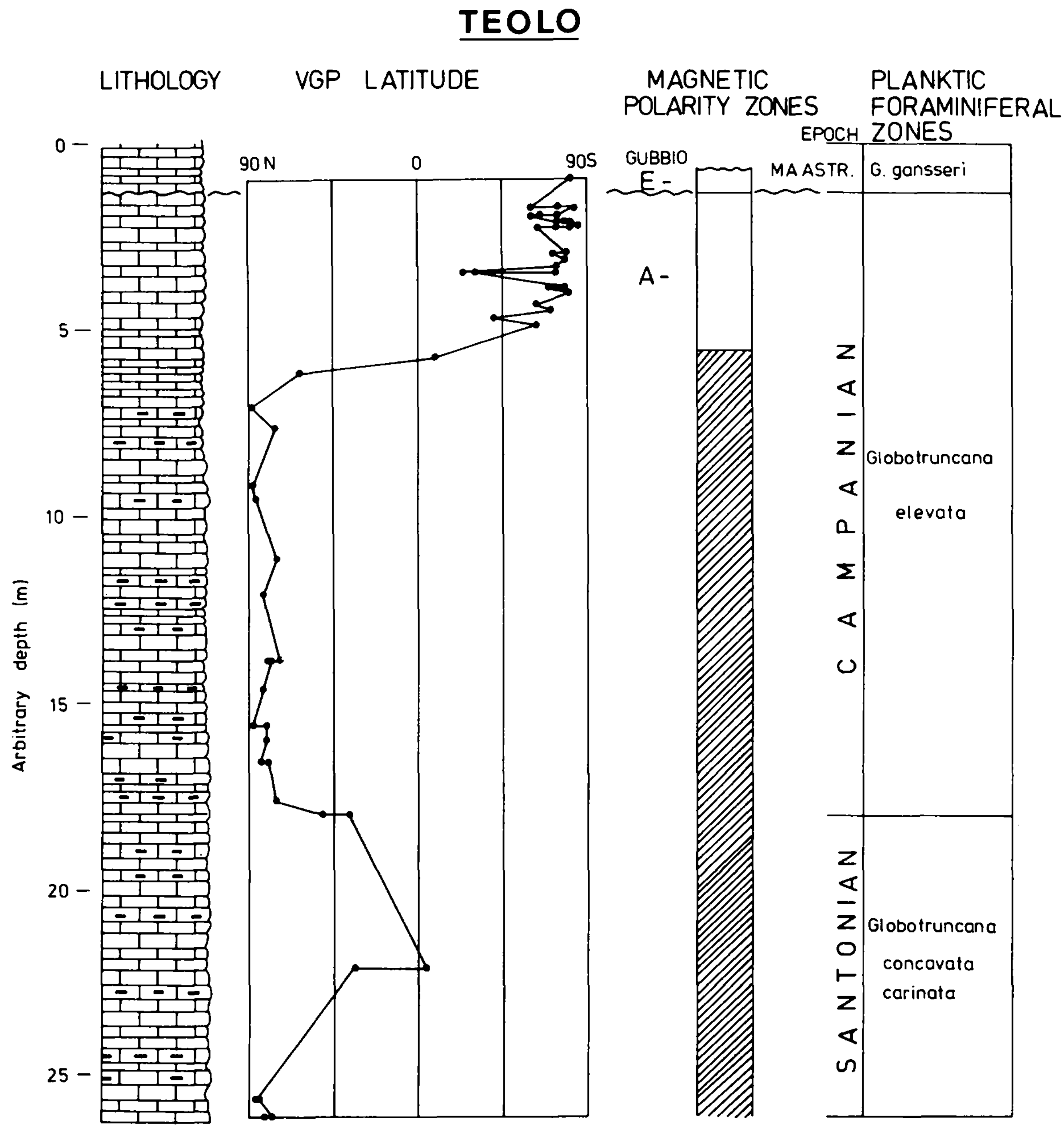



Fig. 7. The stratigraphy for the Teolo section (key as in Fig. 4).

overlain by the middle Maastrichtian *Globotruncana gansseri* Zone. A stratigraphic gap therefore exists between these two zones, it embraces the Upper Campanian and Lower Maastrichtian and polarity zones B +, C −, D + are missing. An abrupt change in lithology, but no hard-ground, can be observed at this discontinuity level. The Maastrichtian, less than 2 m thick and entirely represented by the *Globotruncana gansseri* Zone, ends with a spectacular hard-ground, bear-

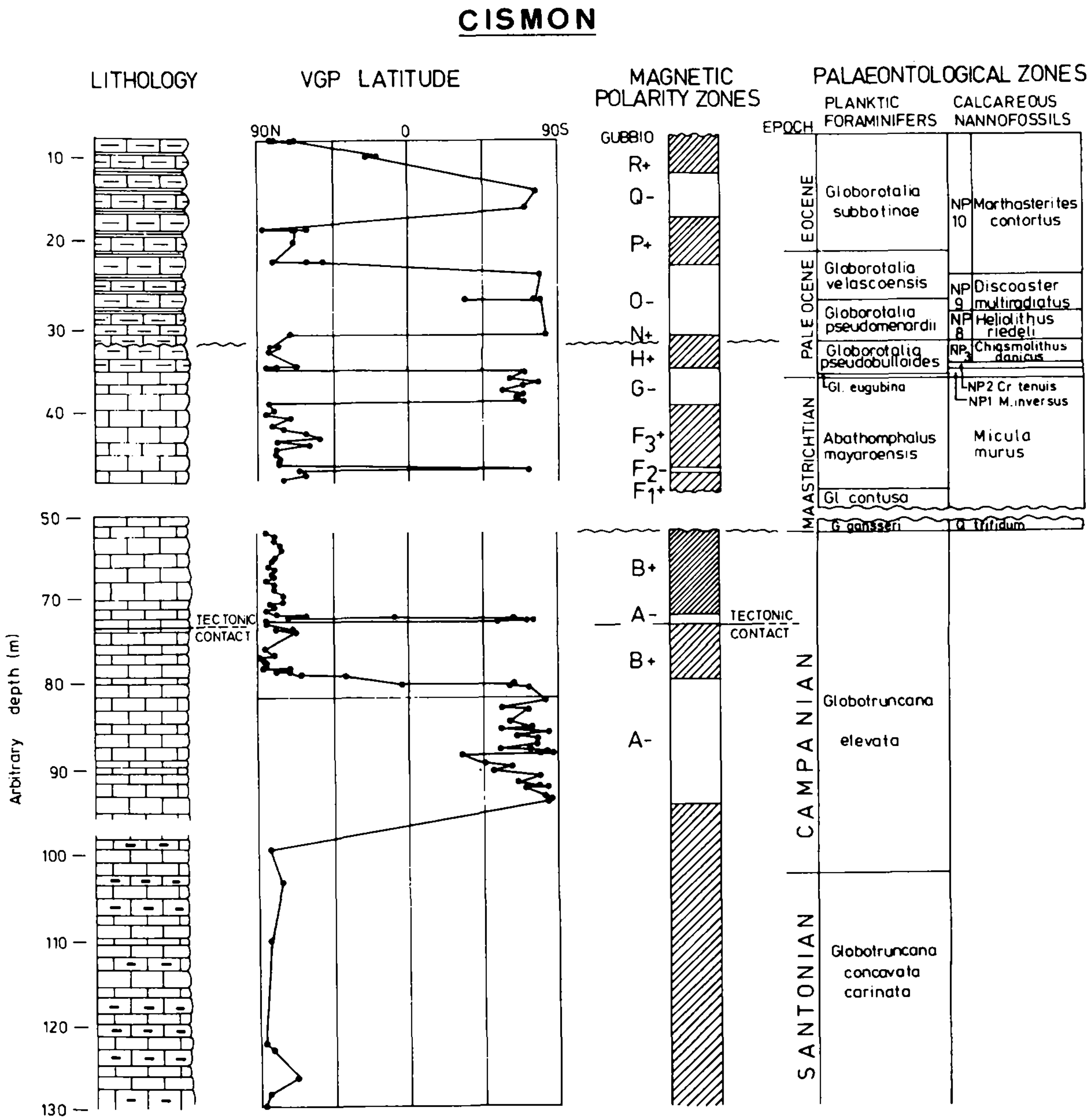



Fig. 8. The stratigraphy for the Santonian to Eocene section at Cismon. The Cretaceous stratigraphy below this has been previously published [17] (key as in Fig. 4).

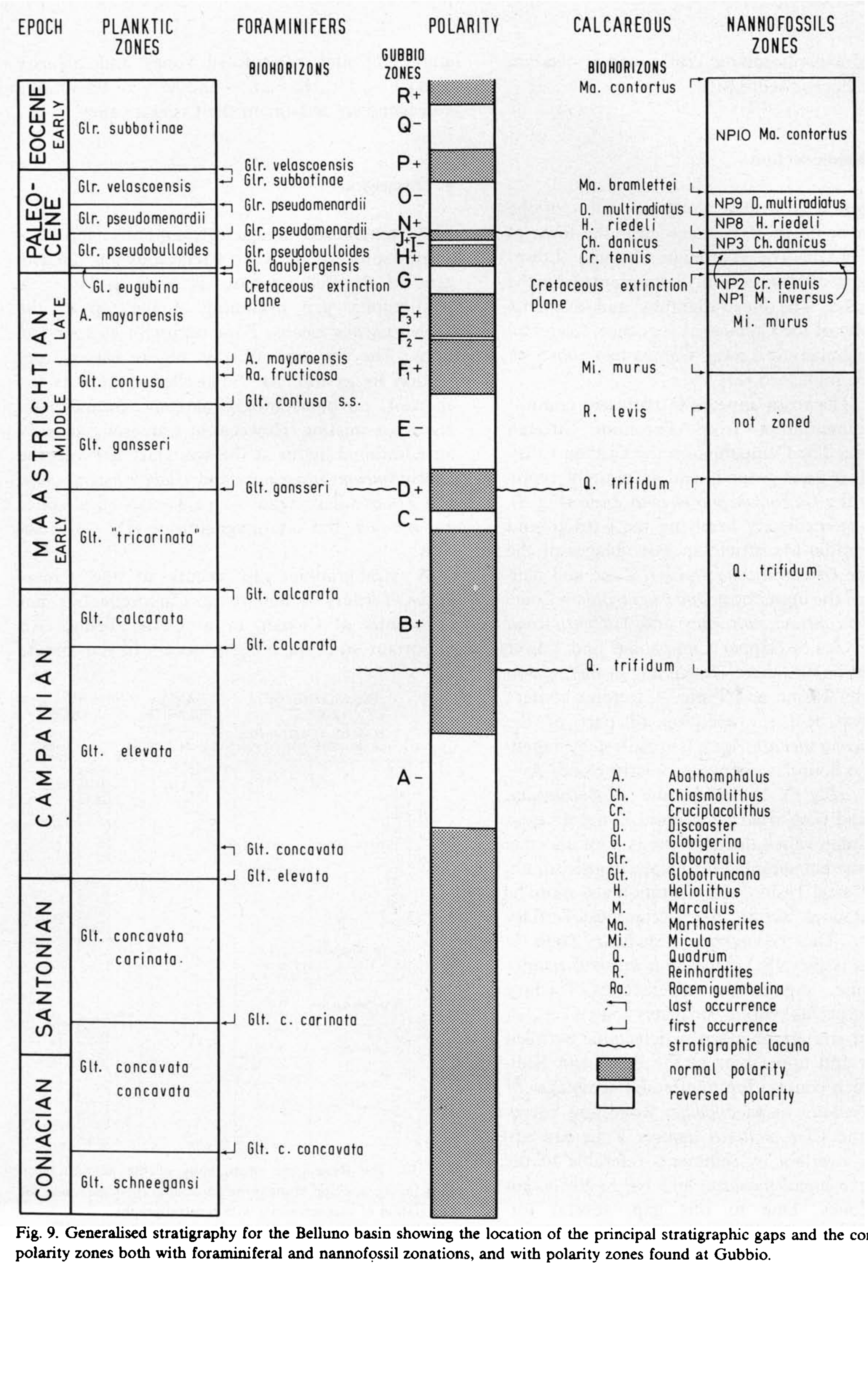



Fig. 9. Generalised stratigraphy for the Belluno basin showing the location of the principal stratigraphic gaps and the correlation of polarity zones both with foraminiferal and nannofossil zonations, and with polarity zones found at Gubbio.

ing ferruginous-phosphatic crusts, and is overlain by Lower Eocene sediments.

## 7. The Cismon section

The section is located along the valley of the Cismon river north of Fonzaso, near the town of Feltre (Fig. 2). The Turonian through Lower Eocene part of this section is represented by the Scaglia rossa. The biostratigraphy and magnetostratigraphy of the Cretaceous sequence, from Upper Valanginian to Lower Campanian, have already been published [17].

The Scaglia rossa appears to represent continuous sedimentation from Turonian through Campanian. The Campanian in the Cismon valley ends with a hard-ground, and is entirely represented by the *Globotruncana elevata* Zone (Fig. 8). The beds immediately overlying the hard-ground contain middle Maastrichtian assemblages of the base of the *Globotruncana gansseri* Zone and nannofossils of the uppermost *Quadrum trifidum* Zone. The *Globotruncana calcarata* and *Globotruncana tricarinata* Zones (Upper Campanian and Lower Maastrichtian) are therefore missing in this section as at Castel Tesino and Teolo. A tectonic contact which gives rise to repetition of part of the *Globotruncana elevata* Zone is manifest by repetition of the boundary between polarity zones A − and B + (Fig. 8). Although the *Globotruncana gansseri* and *Globotruncana contusa* Zones do exist in the Cismon valley the exposure is poor and this interval was not sampled for palaeomagnetism.

As at Castel Tesino, sedimentation was more or less continuous across the Cretaceous/Tertiary boundary. The *Globigerina eugubina* Zone is present as is the NP 1–*Markalius inversus* nannofossil zone. Again the Cretaceous/Tertiary boundary occurs within polarity zone G −. A significant stratigraphic gap is detectable between the lower and upper part of the Paleocene. Sediments which contain foraminiferal assemblages of the *Globorotalia pseudobulloides* Zone and coccoliths of the *Chiasmolithus danicus* Zone are immediately overlain by sediments referable to the *Globorotalia pseudomenardii* and NP 8–*Heliolithus riedeli* Zones. Due to this gap, several foraminiferal and nannofossil zones and polarity zones I −, J +, K −, L + and M − of the middle Paleocene are missing in the Cismon valley.

## 8. Discussion

A generalised magnetostratigraphy and biostratigraphy for the Late Cretaceous and Palaeogene of the Belluno basin is given in Fig. 9. A stratigraphic gap beginning at the top of the *Globotruncana elevata* Zone occurs in all four sections. The duration of this hiatus varies from section to section. At Carcoselle, where it is the shortest, no palaeontological zones or magnetozones are missing. However at Carcoselle, there is an additional hiatus at the boundary between the *Globotruncana tricarinata* and *Globotruncana gansseri* Zones where again no palaeontological zones are missing, but one magnetozone (D2 −) is absent.

A stratigraphic gap occurs at the Cretaceous/Tertiary boundary at Carcoselle but not apparently at Cismon or at Castel Tesino. An important stratigraphic gap occurs in the middle

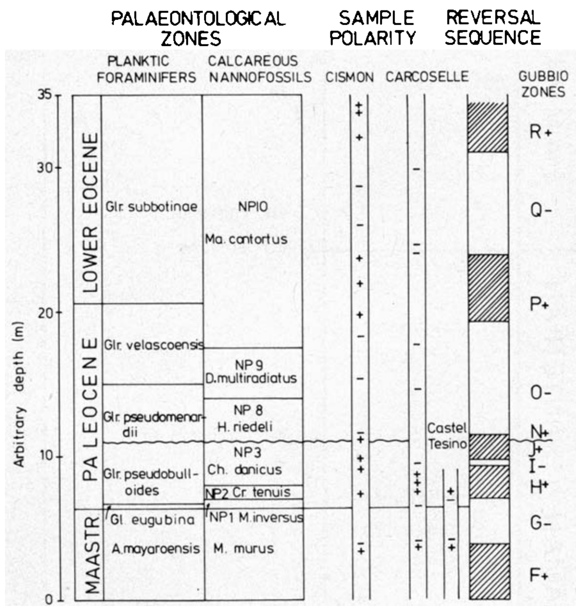



Fig. 10. The Palaeogene stratigraphy of the Belluno basin showing the position of the principal stratigraphic gaps, and the correlation of magnetozones with biostratigraphy.

Paleocene in all the sampled sections, and several palaeontological zones and magnetozones are missing.

The palaeontological ages of the magnetozones in these Southern Alpine sections (Fig. 9) compares well with those found at Gubbio and the magnetozones are labelled in accordance with the Gubbio nomenclature [1,18].

The Palaeogene magneto- and biostratigraphy of the Belluno basin is given in more detail in Fig. 10. The correlation of magnetozones with both foraminiferal and nannofossil zonations should be useful elsewhere although there is here a significant stratigraphic gap in the middle Paleocene. Note that the Cretaceous/Tertiary boundary occurs within zone G −. The magnetostratigraphy

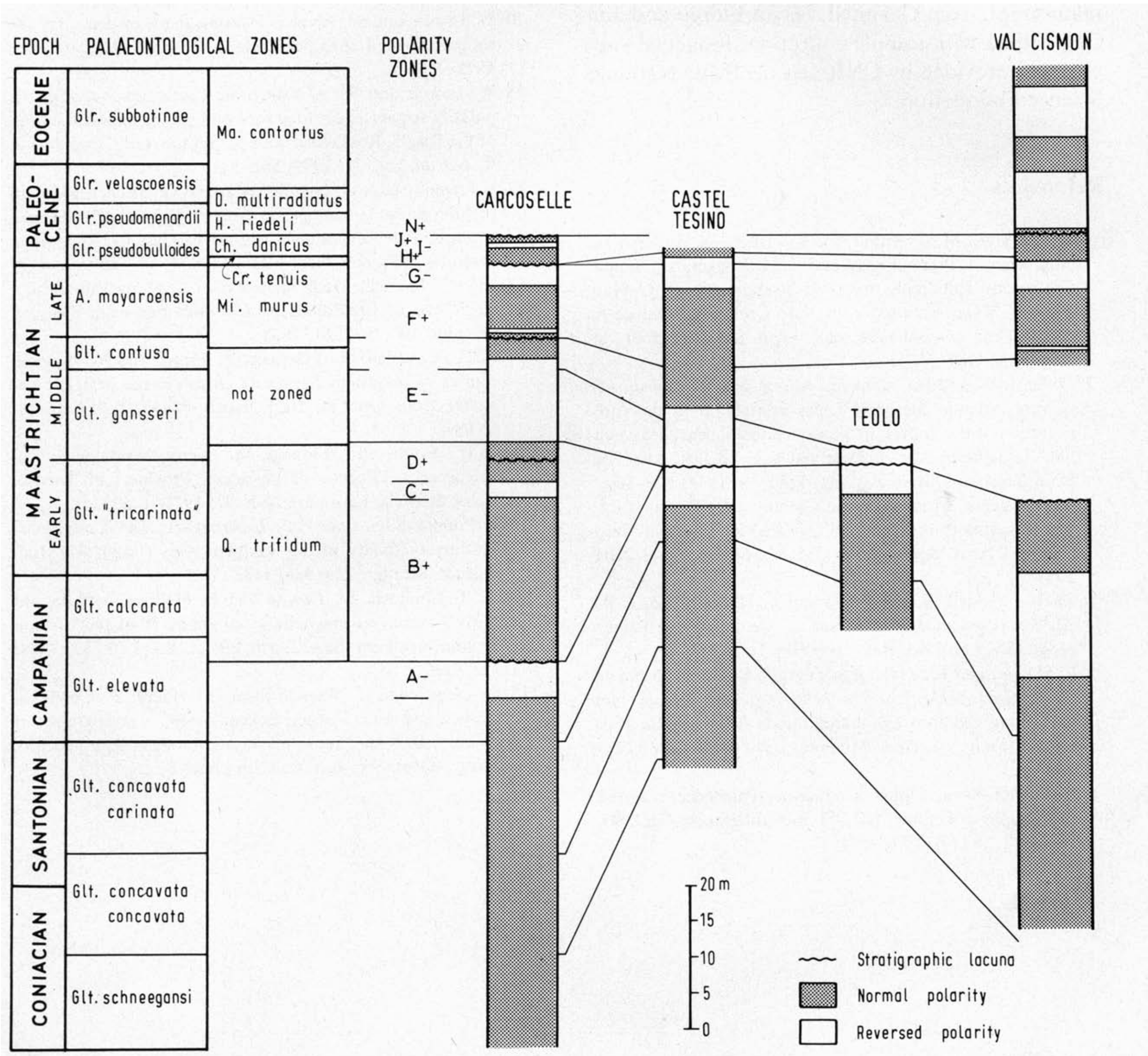



Fig. 11. The palaeontological and palaeomagnetic data give a precise correlation between the four lithologically-uniform sections allowing variations in sedimentation rate and duration of hiatuses to accessed.

together with the palaeontology from these four sections allows very precise stratigraphic correlation and relative dating of these lithologically uniform sections (Fig. 11).

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