Astronomical tuning of the La Vedova section between 16.3 and 15.0 Ma. Implications for the origin of megabeds and the Langhian GSSP

Supplementary Material

Supplementary material A

Here, supplementary information on the succession of the Lower La Vedova section are presented. Photographs of Figures A1a-d show details of the alternation of more indurated and prominent limestones (megabed) and more marl intervals, from the top of the section to Megabed V. Figure A1d shows the different outcrop conditions of Megabeds VII and VI in 2008, when the section was sampled, and in summer 2012 after winter storms.

In Figure A2 it is shown a detailed biostratigraphic correlation between the two sides of the fault revealed by the much improved outcrop conditions after winter storms during 2012. The distribution pattern of selected taxa (the planktonic foraminifer *Globoturborotalita woodi* gr. and *Globoquadrina dehiscens* and the calcareous nannofossil *Helicosphaera ampliaperta*) allowed the correlation of the megabeds between the two sides of the fault, clearly indicating that one megabed was missing in the composite section previously published in Turco et al. (2011a). The comparison of the internal pattern of the megabeds in the revised composite section of the Lower La Vedova Beach section with that of the 7 megabeds very well exposed along the cliffs close to Ancona suggests that the missing megabed is Megabed VI. This is further confirmed by the occurrence of a *G. dehiscens* peak close to the top of Megabed VI and two ash layers above it both at La Vedova and Ancona (Fig. A3).

Supplementary material B

In this part, an alternative tuning to precession/insolation based on the opposite phase relation of limestone beds (and associated Ca-maxima) with precession and insolation cycles is presented (Fig. B1). The limestone beds have been tuned to precession maxima/summer insolation minima on the basis of the isotope signature, i.e. heavier values of bulk $\delta^{18}O$ and $\delta^{13}C$ isotopes observed in limestone beds (Mader et al. 2004).

Figures Captions

Figure A1a-d. Pictures of the Lower La Vedova Beach section showing: a-c) the succession of the megabeds *XIII* to VI; (megabeds and the stratigraphic height of their base and top in the lithologic log are indicated); d) comparison of the exposure conditions of Megabeds VII and VI in 2008, when the section was sampled, and in 2012 after the winter storms.

Figure A2. Biostratigraphic correlation of the megabed interval between the two sides of the fault, that underlies the new composite used in the present study, and comparison of the improved logs of the Lower La Vedova Beach on both sides of the fault (this study) with the previous log published in Turco et al. (2011a).

Figure A3. Comparison of the succession of the megabeds II to VII in the revised log of the Lower La Vedova Beach section with that exposed in the coastal cliffs near Ancona. The *G. dehiscens* peak and two new ash-beds are indicated.

Figure B1. Alternative tuning of the MS, Rb/Sr, Rb/Al, Ti/Al and Ca/Al 3 pma records of the Lower La Vedova Beach section to the Laskar $2004_{(1,1)}$ 65N lat summer insolation. The Ca/Al maxima (and associated MS, Rb/Sr, Rb/Al, Ti/Al) have been tuned to precession maxima/summer insolation minima. The tie-points used for the tuning are indicated by crosses.

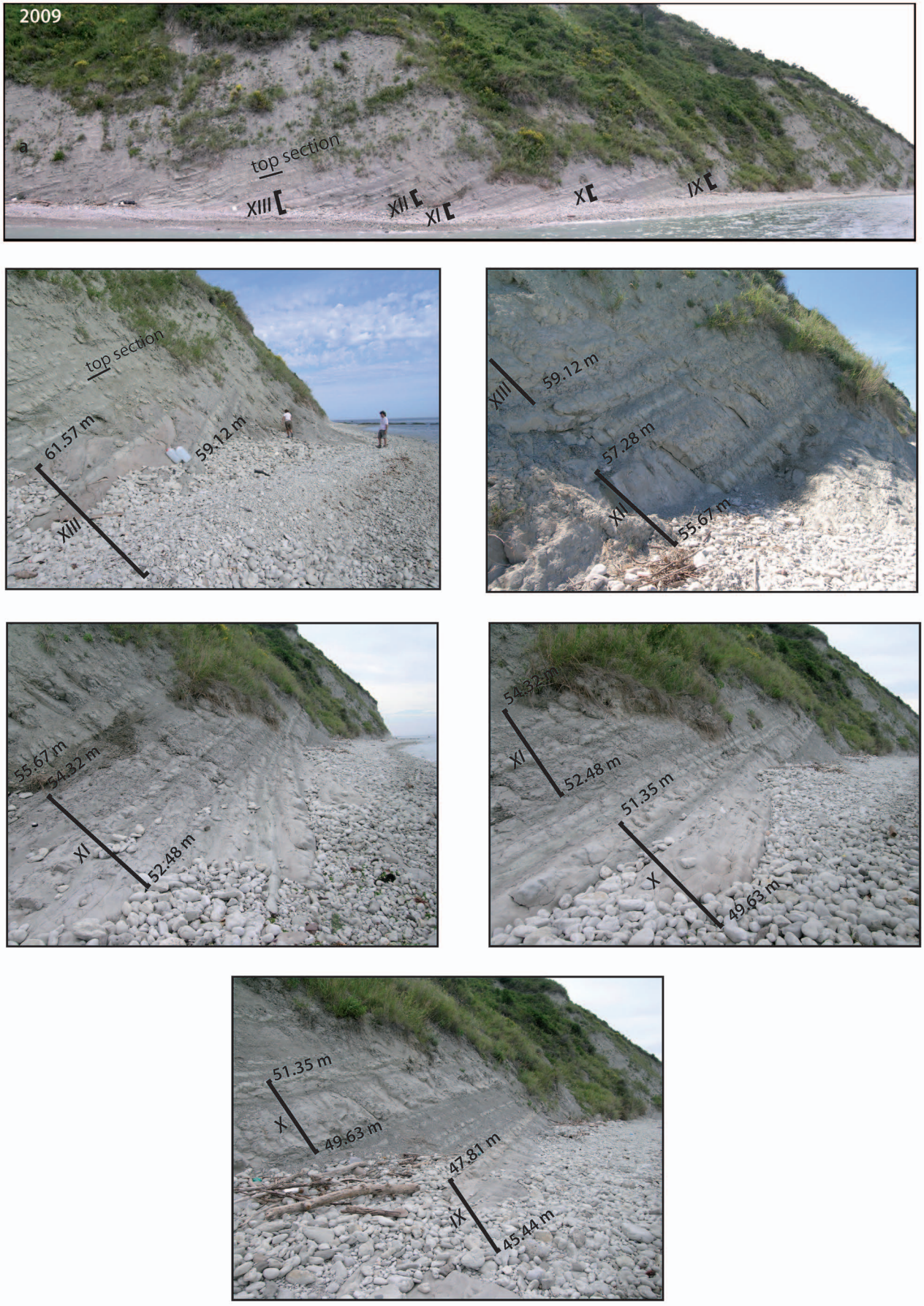
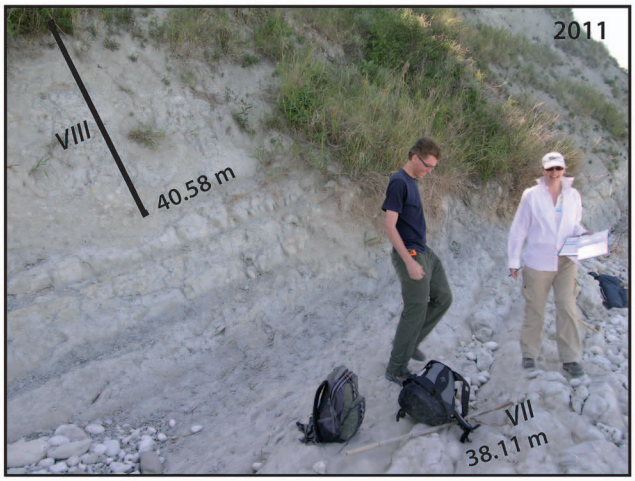

2009
a
top section
XIII
XII
XI
X
IX
top section
61.57 m
59.12 m
XIII
XIII
59.12 m
57.28 m
XII
55.67 m
55.67 m
54.32 m
XI
52.48 m
54.32 m
XI
52.48 m
51.35 m
X
49.63 m
51.35 m
X
49.63 m
47.81 m
IX
45.44 m

Figure A1_a.


2009
VIII
VII
VI
V
IV
III
II
I


2011
IX
VIII
40.58 m

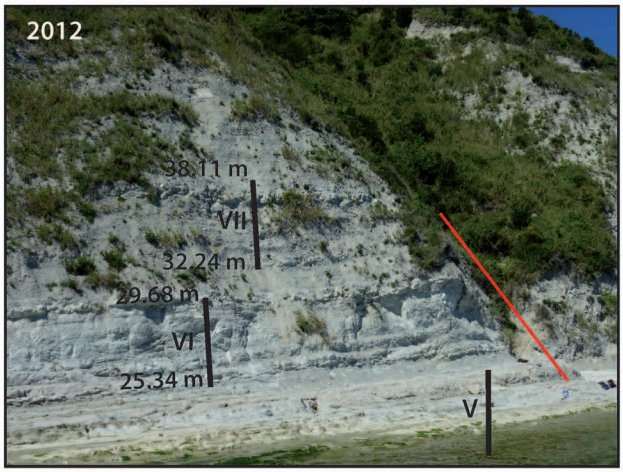

2011
VIII
40.58 m
VII
38.11 m


2011
38.11 m
VII
32.24 m
VI

Figure A1_b.


2009
VIII
VII
VI
V
IV
III
II
I


2012
38.11 m
VII
32.24 m
29.68 m
VI
25.34 m
23.69 m
V


2012
38.11 m
VII
32.24 m
29.68 m
VI
25.34 m
V

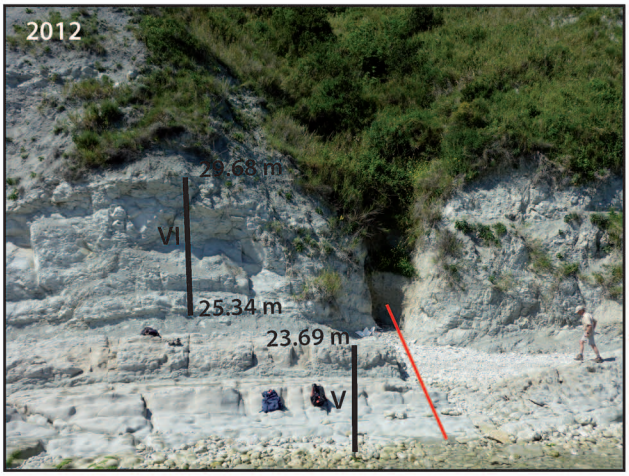

2012
VI
25.34 m
23.69 m
V

Figure A1_c

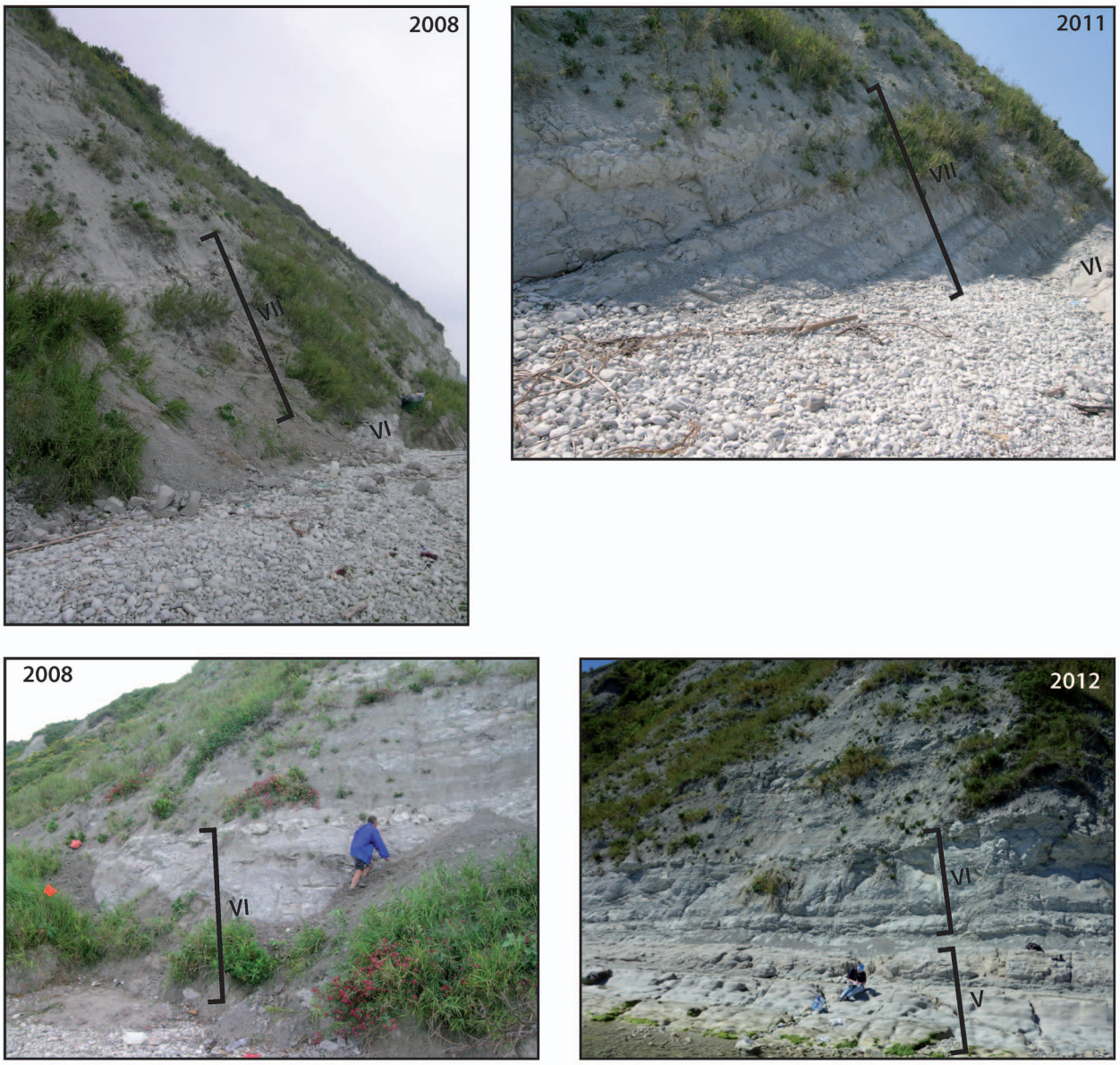


Figure A1_d

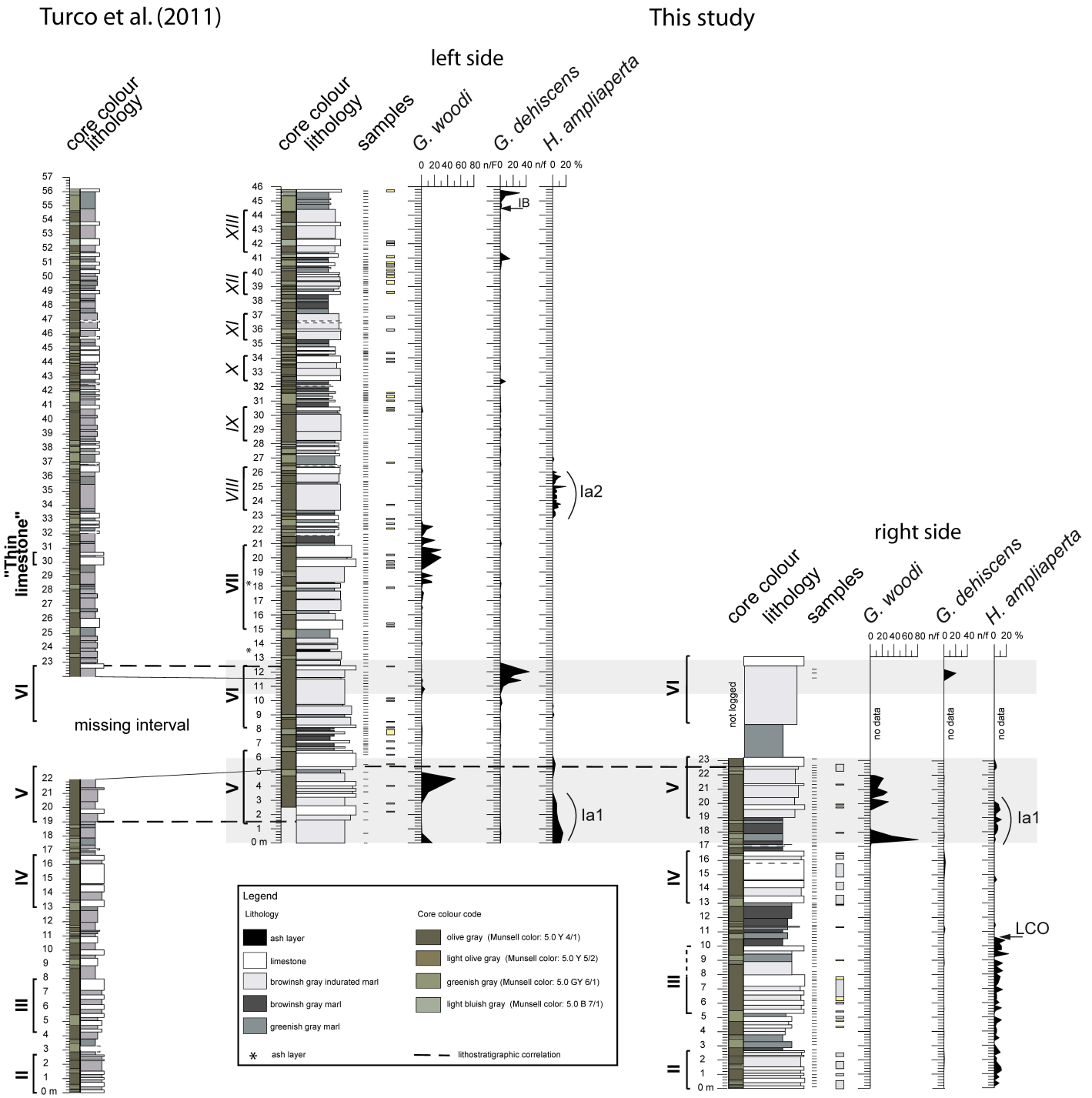
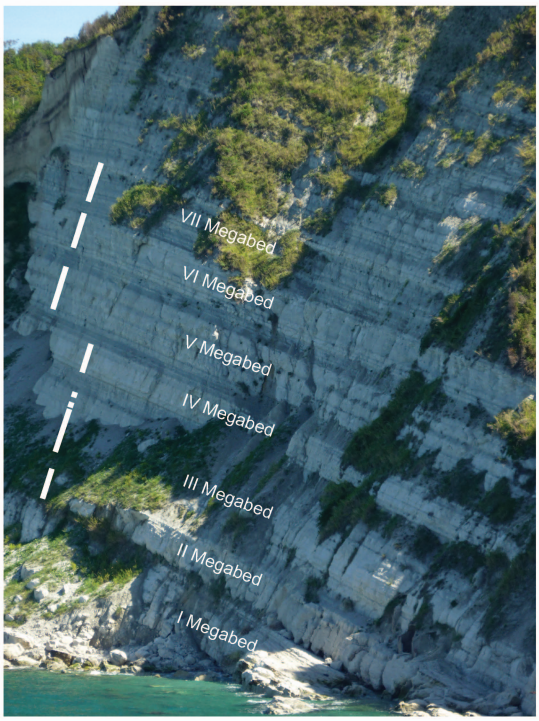
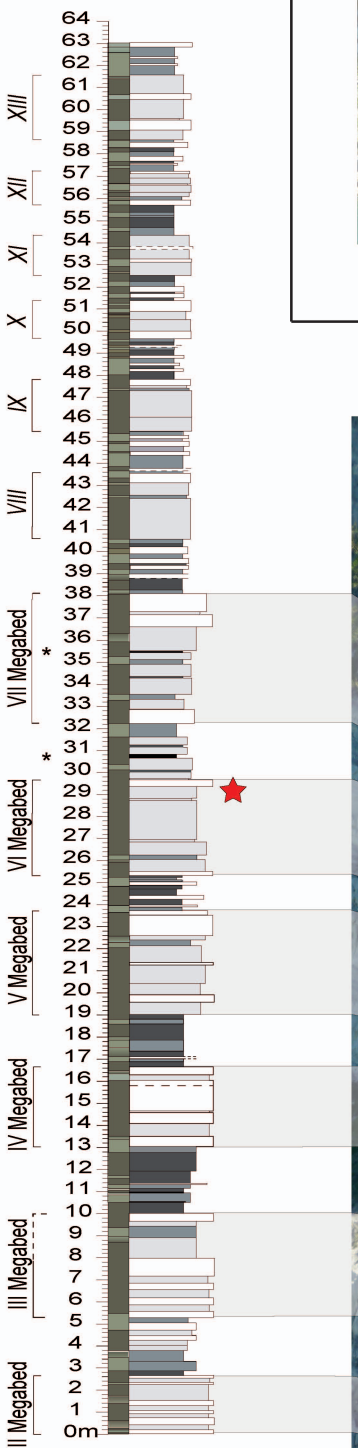

Turco et al. (2011)
This study
left side
right side
core colour
lithology
samples
G. woodi
G. dehiscens
H. ampliaperta
0 20 40 60 80 n/F
0 20 40 n/f
0 20 %
"Thin limestone"
missing interval
IB
Ia2
Ia1
LCO
not logged
no data
Legend
Lithology
ash layer
limestone
browinsh gray indurated marl
browinsh gray marl
greenish gray marl
ash layer
Core colour code
olive gray (Munsell color: 5.0 Y 4/1)
light olive gray (Munsell color: 5.0 Y 5/2)
greenish gray (Munsell color: 5.0 GY 6/1)
light bluish gray (Munsell color: 5.0 B 7/1)
lithostratigraphic correlation

Figure A2

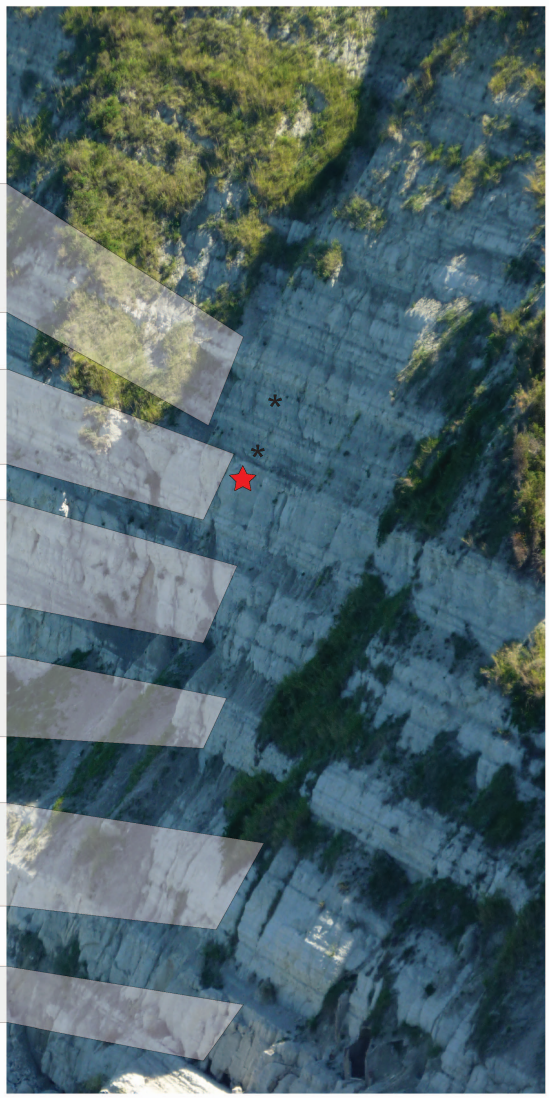
Cliffs close to Ancona



Lower La Vedova Beach section (this study)



Cliffs close to Ancona



* : ash layers

★ : *G. dehiscens* peak

Figure A3.

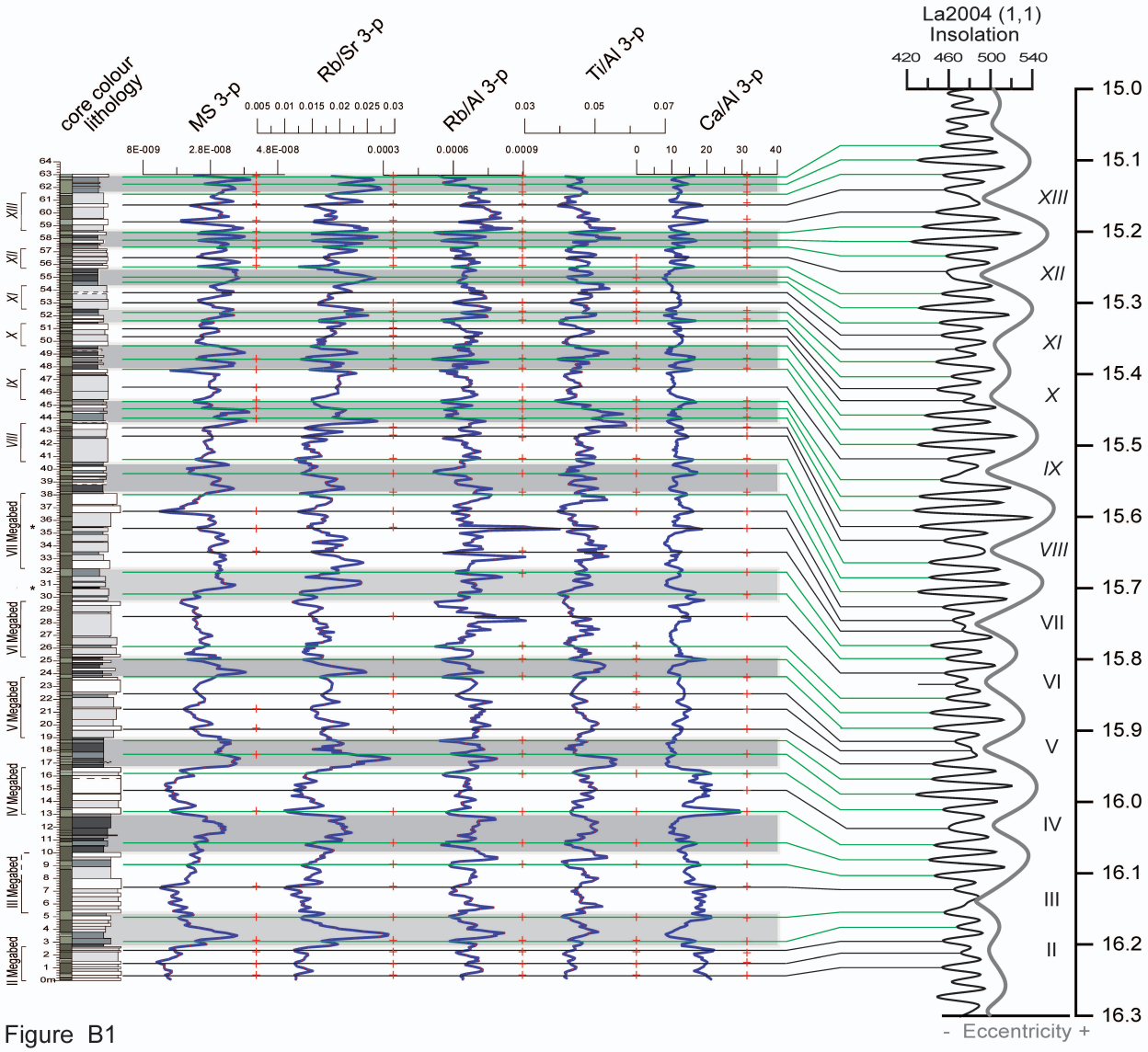

core colour lithology
MS 3-p
Rb/Sr 3-p
Rb/Al 3-p
Ti/Al 3-p
Ca/Al 3-p
La2004 (1,1) Insolation
420 460 500 540
0.005 0.01 0.015 0.02 0.025 0.03
0.03 0.05 0.07
8E-009 2.8E-008 4.8E-008 0.0003 0.0006 0.0009 0 10 20 30 40
XIII Megabed
XII Megabed
XI Megabed
X Megabed
IX Megabed
VIII Megabed
VII Megabed
VI Megabed
V Megabed
IV Megabed
III Megabed
II Megabed
XIII
XII
XI
X
IX
VIII
VII
VI
V
IV
III
II
15.0
15.1
15.2
15.3
15.4
15.5
15.6
15.7
15.8
15.9
16.0
16.1
16.2
16.3
- Eccentricity +

Figure B1