PRELIMINARY RESULTS ON THE PALOMAGNETISM OF UPPER PERMIAN VERRUCANO LOMBARDO SANDSTONES FROM VAL CAMONICA AND OF UPPER TRIASSIC VAL SABBIA SANDSTONES FROM VAL BREMBANA
(Southern Alps)

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RIASSUNTO - Risultati preliminari sul palomagnetismo delle arenarie del Permiano Superiore del Vercors Lombardeo e delle arenarie di Val Sabbia del Triassico Superiore di Val Brebbena (Alpi Orobie). Questo articolo riporta alcuni risultati preliminari sul palomagnetismo delle arenarie del Permiano Superiore del Vercors Lombardeo (48 campioni, Val Camonica) e delle arenarie di Val Sabbia di età Carnica Inferiore-anni-
no (34 campioni, Val Brebbena). L'obiettivo è quello di confermare che il limite inferiore di unità campioni non per-
mette di trarre alcuna conclusione definitiva. Complementare è l'interesse sempre presente del polo magnetico Verte-
vole (VGP) calcolato dalla componente componentare isotraite nelle arenarie del Vercors Lombardeo (Lat=46,2, Long=-237,0, A=14,3, K=46, N=31) e in stretto accordo con i dati relativi al Permiano Superiore delle Alpi Mo-
ridoniane e cade sulla porzione Permiano-Fam. da Curva di Migrzione Apparente dei Poli (APWP) del’Africa e dell’Europa nausatia in corrente africana. D’altra canto, il VGP ottenuto dalla componente componentare isotraite nelle arenarie di Val Sabbia (Lat=-56,6, Long=-20,10, A=36,8, K=46, N=7) cade all’ovest della porzione pro-
currite dell’APWP del’Africa e dell’Europa. Viene incluso proposito e discusso un APWP per le Alpi Mor-ridoniane per l’intervallo di tempo compreso tra le (e) (Unificare) (Carbonifero Superiore) l’Austro-Triasico (Triasico-Mesozoico).

SUMMARY - This paper reports preliminary results on the palomagnetism of the Upper Permian Verrucano Lombard sandstones (two sites, 29 specimens, Val Camonica) and of the Lower Middle Carnian (Upper Triassic) Val Sabbia Sandstones (three sites, 34 specimens, Val Brebbena). The results show that the limited number of specimens and the low / field tests indicate to contain the cone of acquisition of the magnetic remanence do not lead to any conclusive extraction. Nonetheless, it is interesting to observe that the Virtual Geomagnetic Pole (VGP) calculated from the Vercors Lombardeo Sandstones’ characteristic component (Lat=46,2, Long=-237,0, A=14,3, K=46, N=31) is in agreement with the Upper Permian data from the Southern Alps, and lies on the paleo-motion of both the African and the related European Apparent Palaeo-Wave Path (APWP). On the other hand, the Val Sabbia Sandstones’ VGP (Lat=-56,6, Long=-20,10, A=36,8, K=46, N=7) lies W of the Upper Triassic portion of the African and European APWP. According to literature, the tentative Southern Alps APWP for the Stephanian (Late Carboniferous) to La-
turian (Middle Triassic) time interval is proposed and discussed.

INTRODUCTION

It has been known for a long time that the Southern Alps are suitable for palomagnetic analysis, (see compilation by van Den et al., 1993 and Billa et al., 1989). Investigations on Upper Palaeozoic to Tertiary rocks started in the early 60’s. In particular, in the Up-

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BASIC LITHOLOGICAL DESCRIPTION

The Verrucano Lombardo Ss. and the Val Sabbia Ss. represent two relevant terrigeneous events in the Permian-Triassic sedimentary sequence of the western Southern Alps.

Verrucano Lombardo Sandstones

According to the data of PINTANA & ZUPPA (1992) and following the classification of FOLK (1974), in the Val Corsaica area VL Ss. consist of volcanic arcites, fieldspathic litharenites and subordinately lithic arkose (composition ranging from Q-F-L to Q-L-F to Q-L-QF, detrital modes after DICKENSON, 1970) (SCHUH et al., 1993). Because of the lack of fossil content, VL Ss. are difficult to date. However, a Late Permian age (Tata-
rian to Cismonian) for the VL Ss. deposited above the Artisianian-Lambian Collio and Tremizzo basins has been suggested by CASSINS et al. (1993). The VL Ss. are generally considered the product of fluvial deposition, from coarse alluvial fans (Laguneese) to proxi-
mal braided rivers (Corsaica Alps) and distal braided rivers (Bergamo Alps). The vertical evolution of the VL red beds is characterized by an overall fining-upward trend, from allu-

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vial fan conglomerates to braided sand-dune deposits (CASSINS et al., 1988). The presence of pedogenic calcrites and gypsum along with other sedimentological characteristics suggest semi-arid conditions (CASSINS et al., 1988).

It has to be emphasized that the paleomagnetic directions obtained in the Pocono Mountains show the best grouping at somewhat less than full correlation, which may suggest a tectonic reorganization. However, this possibility is not well supported because, as MUTTIEN & KENT (1994) report, a 400° decrease by a factor of only 0.9 in the precision parameter of this first-order (8RPA) map of tilt correction compared to 0(PP) tilt correction is not statistically significant.
Val Sabbia Sandstones

The Val Sabbia Sandstones are Early-Middle Carnian (Late Triassic) in age and consist of greenish-grey to red fine to medium-grained siltstones and sandstones. In Val Brembana (S. Gallo borehole, GARGANTI & JADOL, 1985) VS Ss. are subdivided into three stratigraphically superposed members: a lower green (132 m-thick), an intermediate red (about 338 m-thick) and an upper green member (about 50 m-thick). Red and green pigmentations are due to the early diagenetic formation of, respectively, hematite and chlorite (GARGANTI & JADOL, 1985). Palynomagnetic samples have been collected in the intermediate hematite-bearing red member. Petrographically VS Ss. mostly consist of plagioclase-bearing volcanic gravels (classification after FORA, 1974), and show a fairly homogeneous composition ranging from Qr-G.L. to Qz-E.D. (GARGANTI & JADOL, 1985). According to GARGANTI & JADOL (1985), the Carnian sediments of Val Brembana are arranged in a regressive megasequence marking the transition from lagoonoid facies (basal GOMO Fl.) to a lower and sub-boreal delta plain palaeoenvironment, progressing as a consequence of a great supply of ter-
PALEOMAGNETIC TECHNIQUES

All the specimens were taken with a portable water-cooled drill and oriented by means of a magnetic compass. Successively, in the laboratory, they were subjected to computerized thermal demagnetization. Remanence measurements were performed in a 2G 3-axis cryogenic magnetometer located in a magnetically shielded room. For some of the specimens, mineral alterations after each heating step were monitored with a Bartington Susceptibility Meter MS2. Principal Component Analysis (Kirschvink, 1980) was applied to

Val Sabbia Red Sandstones

Fig. 2 - (A) Examples of orthogonal projections of thermal demagnetization data and (B) curves of thermal decay of Natural Remanent Magnetization (NRM) for two Val Sabbia St. samples. Solid squares are projections onto the horizontal plane, open circles onto the vertical plane. All diagrams are in situ coordinates. See text for discussion.

2b...
PALEOMAGNETIC DIRECTIONS

VS Ss. sites VSI, VS2 and VS3 (red sandstones)

In situ orthogonal projections of thermal demagnetization data indicate the presence of two stable magnetization components: a soft component consistent with the present-day magnetic field is removed between 100-200 and 350 °C, whereas a characteristic component oriented N-and-down is successively isolated from about 350-400 to 600-625 °C (fig. 2A).

The unblocking temperature spectra of NRM indicate a maximum unblocking temperature for the stable remanence of about 625-650 °C. Above this temperature the NRM becomes highly unstable and viscous, probably because of mineral alteration during heating. When mineral alteration is developed at temperatures somewhat lower than 600 °C, the characteristic component cannot be precisely isolated and the sample direction is rejected (30% of samples rejected at site VSI, 30% at site VS2 and 16% at site VS3).

Although the remanence cannot be completely resolved, the maximum unblocking temperature of the stable remanence and the red colour of the sediment confirm the presence of hematite as the main magnetic carrier.

After correction for bedding tilt the characteristic component site-mean directions are oriented NW-and-down (fig. 3A, tab. I), and the overall mean direction is Declination -352.3, Inclination -24.2 (fig. 3B, tab. I).

VL Ss. sites VLI and VL2 (red sandstones)

Two sites have been sampled in VL Ss. medium-grained red sandstones. In situ orthogonal projections of thermal demagnetization data (fig. 4A) indicate the presence of three progressively isolated components. After removal of a soft component carrying the present-day magnetic field, a "B" component is isolated between 200 and 500 °C. This component shows dual polarity at site VL2 (with 94% of normal directions) and is oriented NW-and-down (SE-and-up), whereas at site VLI it bears only reversed directions oriented SE-and up. A characteristic component directed SE-and-up and bearing unblocking temperature spectra ranging from about 625 to 685 °C at site VL2 and 500 to 665-685 °C at site VLI is finally isolated.

The unblocking temperature spectra of NRM suggest the presence of hematite (fig. 4B). According to FONTEAU & ZUFFA (1982), hematite was originated during the early diagenesis as consequence of Fe oxidation in subaerial conditions. No mineral alteration seems to take place during heating. At site VLI the 46% of the samples did not yield resolvable characteristic component directions.

After correction for bedding tilt the VL Ss. "B" component directions are oriented NW-and-down (SE-and-up) at site VL2 and SE-and-up at site VLI (fig. 3, tab. I). At site VLI the "B" directions are highly scattered and do not show a Fisherian distribution.

As regards the characteristic component, after correction for bedding tilt the VL Ss. site-mean directions are oriented SE-and-up at both sites (fig. 6A, tab. I). The overall mean is Declination +148.9, Inclination -50.3 (fig. 6B, tab. I).

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DISCUSSION

Two sites in the Versacano Lombardo Ss and three sites in the Val Sabbia Ss provided a stable characteristic remanence. No field test is available to bracket the age of this remanence. The author is perfectly aware that the limited number of sites/specimens and the lack of age-constraining tests do not lead to any exhaustive conclusion. Nevertheless, some observations can be made.

Discussion on the VL SS and VS SS Virtual Geomagnetic Poles

The Southern Alps are thought to be autochthonous. All Paleozoic to Cenozoic paleomagnetic directions from the Southern Alps taken from literature data (see the compilation by Van der Voo, 1993) generally appear to be internally consistent and show an African

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Fig. 3 - Stereographic projections of (A) the tilt corrected characteristic remanence sampled in the Val Sabbia Ss sites, provided with the 95% zone of confidence around the mean and of (B) the mean direction of the characteristic remanence of each site before and after correction for tilt.

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affinity, being 45° to 50° counter-clockwise rotated with respect to stable Europe for pre-Late Cretaceous times. This internal consistency led Van Den Berg & Zijderveld (1962) to construct a Permian to Tertiary APWP for the eastern Southern Alps which, at least for the south- and northward movements, is similar to the Africa one.

Figure 7A reports the Stephanian (Upper Carboniferous) to Upper Triassic poles of Table 2, characterized by a quality index Q=26 (Q after Van Der Voo, 1989: pole 1 in Stephanian (296-263 Ma) [All ages according to the DNAG time scale, PALMER (1983)]; poles 2 to 6 are Stephanian to Lower Permian (296-258 Ma), poles 7 to 13 are Upper Permian to Lower Triassic (258-240 Ma), vs. C.e. is the Virgilian Geomagnetic Pole (VGP) calculated from the tilt corrected site-mean characteristic directions of VL Sta. sites (Upper Permian) (tab. F). Stephanian to Lower Permian and Upper Permian poles are well grouped. Moreover, vs. C.e. pole is in full agreement with the Upper Permian poles.

Poles 14 to 15 are Permian to Triassic, poles 16 to 20 are Triassic (245-208 Ma), vs. C.e. is the VGP calculated from the tilt corrected site-mean characteristic directions of VS sites (Lower-Middle Cretaceous). Triassic poles show a more scattered distribution and generally lie north of the Permian ones. Pole 18, from Upper Anisian limestones from the western Southern Alps (BALONI & MUTTINO, unpublished data), and pole 20 from Norian (Upper Triassic) dolostones from the Vicentinian Alps (De Boe, 1963) are the only Triassic poles obtained from Southern Alps limestones. The anomalous position of pole 20 (with a quality index Q=2) raises the suspicion either of remagnetization or of local tec-

| Table 1: Statistical parameters of the palaeomagnetic directions isolated in the Vencuano Lombardo Sta. and in the Val Subba Sta. |
|---|---|---|---|---|---|---|---|---|
| Site | V101 | V102 | V103 | V104 | V105 | V106 | V107 | V108 |
| N (%) | 9 (100) | 8 (100) | 9 (100) | 11 (100) | 8 (100) | 10 (100) | 11 (100) | 8 (100) |
| D (°) | 350.0 | 260.0 | 356.0 | 351.0 | 356.0 | 351.0 | 356.0 | 351.0 |
| I (°) | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Dc (°) | 350.0 | 260.0 | 356.0 | 351.0 | 356.0 | 351.0 | 356.0 | 351.0 |
| Ic (°) | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| ktc | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 |
| ktc | 8.2 | 8.2 | 8.2 | 8.2 | 8.2 | 8.2 | 8.2 | 8.2 |
| LAT (°) | 50.4 | 50.4 | 50.4 | 50.4 | 50.4 | 50.4 | 50.4 | 50.4 |
| LONG (°) | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 |
| CAM (°) | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 | 30.8 |

Conv.: component assignment; N: number of samples used for statistical analysis and number of sites for the mean directions and pole positions; (%) number of V105 samples collected in the field. Dc, Lc, Dc, Ic, tc: declin- ation and inclination in site and tilt corrected coordinates, respectively. ktc: precision parameter after tilt correc-
tion, ktc: half-angle of cone of 95% confidence about the mean direction in tilt corrected coordinates. LAT (°) and LONG (°) in geographic coordinates. <LAT> (°) and <LONG> (°) in geographic coordinates of the dip direction. K: precision parameter of the pole.
Finally, the position of the Virtual Geomagnetic Poles calculated from the in situ and tilt corrected site-mean “B” directions of VL 1s, site VL 2 (v12 B. s and v12 B. t), respectively) are more difficult to interpret. As figure 7A shows, v12 B. s lies far off all the plotted Permno-Trias sic axes, whereas, after correction for tilting, pole v12 B. t. c gets closer to the Stephanian to Lower Permian group of poles.

Verrucano Lomb. Red Sandstones

![Diagram](image)

Fig. 4: (A) Examples of orthogonal projections of the demagnetization data and (B) curves of thermal decay of Natural Remanent Magnetization (NRM) for two Verrucano Lombardo sites; samples site VL2. Solid squares are projections onto the horizontal plane, open circles onto the vertical plane. All diagrams are in situ coordinates. See text for discussion.

A tentative Stephanian to Anisian APWP for the Southern Alps

Mean poles of Stephanian to Lower Permian (Lat. 39°N, Long. 245°E) and Upper Permian to Lower Triassic (Lat. 47°N, Long. 238°E) are reported in table II (bold lines) and plotted in figure 7B. Among the more controversial Triassic axes, fig. 7B reports the recent and well dated Upper Anisian pole 16 (Lat. 62°N, Long. 231°E). The tentative APWP obtained from these poles (striped circles) is compared with (i) the APWP of West Gondwana in northwest African coordinates (Van der Voo, 1993) (solid diamonds), (ii)
VERRUCA NO LOMBARDO
"B" COMPONENT

In Situ
Tilt Corr.

Site VL2

Site VL1

In Situ
Tilt Corr.

Fig. 5 - Stereographic projections of the in-situ and tilt corrected "B" component directions denoted in the Verrucano Lombardo S.R. sites VL2 and VL1, provided with the 95% cone of confidence around the mean.

The APWP of Gondwana in northwest African coordinates (Van der Voo, 1993) (solid circles) and (iii) the APWP of Europe (Van der Voo, 1993) (open circles), rotated to African coordinates by rotation parameters derived from KLUGER & SCHOUTEN (1986) and SRIVASTAVA & TAPPERT (1986).

The Stephanian to Lower Permian and the Upper Permian to Lower Triassic mean poles from the Southern Alps basically fit the Lower and Upper Permian mean poles of "Africa" and Europe, with the exception of the West Gondwana Upper Permian pole, which hi-

"Africa" is either West Gondwana or Gondwana supercontinent rotated to northwest African coordinates.
to Upper Triassic portion of the APWP of West Gondwana. Finally, the VGP calculated from the Val Sabbia Sa. tilt-corrected characteristic component (Vs Chr) (fig. 7A), not included in the Southern Alps APWP discussed here because too poorly constrained as regards age and statistics, seems to lie W of the Upper Triassic portion of both the West Gondwana and the rotated European APWPs (note that a similar conclusion can be also reached when considering the Vs Sa. VGP calculated from the in situ characteristic directions).

**VERRUCANO LOMBARDO**

Site VL1  
Tilt Corr.

Site VL2  
Tilt Corr.

A)

\[\text{Site vl1} \quad \bullet \quad \text{Site vl2} \quad \triangle \quad \text{Mean}\]

**CONCLUSIONS**

A high unblocking temperature characteristic component isolated in the Upper Permian Verrucano Lombardo Supergroup of Val Camonica, Lombardy yielded a Virtual Geomagnetic Pole in agreement with the Permian portion of both the "African" and the rotated European Apparent Polarity Wander Paths (APWPs). A tentative Southern Alps APWP for
the Stephanian (Late Carboniferous) to Late Anisian (Middle Triassic) time interval is con- structed based on these and literature data.

More controversial is the interpretation of a lower unblocking temperature "B" component isolated in the Verrucano Lombardo Ss. and of the characteristic component obser- ved in the Upper Triassic Prezzo Limestone (pole 18, see note 2), (ii) the poorly constrained age and statistics of the characteristic component isolated in the Val Sabbia Ss. and (iii) the meaning of the Verrucano Lombardo "B" component. These preliminary results encourage to devote some efforts to the paleomagnetism of the Permian to Triassic sedimentary se- quence of the western Southern Alps.

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Fig. 7: (A) Geographic projection of: 1. The Permian in Triassic poles from the Southern Alps (tabl. 2). Poles enclosed in light shadowed patterns are Stepped to Lower Permian, poles in dark shadowed patterns are mainly Upper Permian, with the exception of pole 13 [Sicilia] and 10 [Ladone-Camot]. Poles 14 and 15 are Permian to Triassic and poles 16, 17, 18, 19 and 20 are Triassic. 2. The WGP calculated from the (i) VL Ss. tilt corrected characteristic remanence (cf. C), (ii) the tilt in axis VL2 corrected "B" component dated in VL 3a see VL2 (at 2 B, and (at 2 Bt, respectively) and (iii) the Val Sabbia Ss. tilt corrected characteristic remanence (cf. C).

Geographical projection of: 1. The U. Carboniferous to L. Jurassic portion of the APWP of Van der Voo (1993, tab. 5.8) for W Gondwanas in the coordinate system of NW Africa (abscissa curve and diamonds). 2. The U. Carboniferous to L. Jurassic portion of the APWP of Van der Voo (1993, tab. 5.2) for Gondwanas in the coordinate system of NW Africa (abscissa curve and circles). 3. The U. Carboniferous to L. Triassic portion of the APWP of Van der Voo (1993, tab. 5.1) for U. Europe moved to African coordinates (abscissa curve and circles). 4. Transp. stephanian (U. Carboniferous) to U. Anisian (Middle Triassic) APWP based on data from the Southern Alps (dotted band). Striped circles are all cases of confidence about the poles. Age symbols are as follows: Cir, Upper Carboniferous; StP, Stepha- nian (Upper Carboniferous);Lower Permian; Pl, Lower Permian; Py, Upper Permian; Th, Triassic; eTm, Top, upper Middle Triassic; Upper Triassic; Tp, Triassic; Upper Triassic; Lower Jurassic; R, Lower Jurassic. The ages are based on the DSDP time scale (Palmer, 1983).

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