Zeitschrift: Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

Band: 59 (1979)

Heft: 1-2

Artikel: Some applications of paleomagnetism to geodynamics problems

Autor: Lowrie, W.

DOI: https://doi.org/10.5169/seals-46051

Schweiz. mineral. petrogr. Mitt. 59, 149–155, 1979

Swiss National Committee for the International Geodynamics Project
Working Group 6a (Zurich): Paleomagnetism

Some Applications of Paleomagnetism to Geodynamics Problems

Report by *W. Lowrie**)

Abstract

The contributions of the paleomagnetism group, ETH-Zürich, to geodynamics problems are reviewed. Tectonic applications have shown counterclockwise rotations in the S. Alps and Italy associated with the African plate. Magnetic stratigraphy investigations confirm and date the oceanic magnetic anomaly sequences for most of the Cretaceous.

INTRODUCTION

Paleomagnetism can contribute in two main ways to the interpretation of geodynamics problems. Firstly, the stable directions of remanent magnetization in rocks can be interpreted in terms of local and regional tectonics of the sampled area, in order to associate the region with one of the major global lithospheric plates. Secondly, the sequence of magnetic polarity in paleontologically dated stratigraphic sections can be correlated with corresponding oceanic magnetic anomaly sequences, thereby confirming the geomagnetic reversal history and dating the anomalies and appropriate major plate motions. This report makes no attempt to be comprehensive, but summarizes the contributions of the paleomagnetism group at the ETH-Zürich to these two topics during the International Geodynamics Project.

TECTONIC STUDIES

Tectonic problems cannot be uniquely solved by paleomagnetic studies. However, stable paleomagnetic data serve as parameters that must be taken into account in tectonic reconstructions. Furthermore, paleomagnetic-tectonic reconstructions may be postulated when further supplementary geologic data are available. The investigations summarized here were carried out in the Alps,

*) Institute of Geophysics, ETH-Hönggerberg, CH-8093 Zurich (Switzerland)

Umbria, Southern Italy and Sardinia, in rocks ranging in age from Permian to Miocene. A notable feature of these studies is the nearly ubiquitous evidence for tectonic rotations in the counterclockwise sense.

Paleomagnetic samples were collected from Permian rocks at several sites in the Southern Alps. The data from some localities were not usable for paleoreconstructions because of local tectonic disturbance for which no correction was possible. From three areas of the S. Alps, however, reliable data were obtained which differed from the Permian directions of stable Europe. The directions agree closely with African Permian data, and, taken together with data from other studies in the S. Alps, indicate that a large part of the S. Alps must have behaved as a single tectonic unit, probably as part of the African plate (HEINIGER, 1978).

The remanent magnetizations of samples from the Gurnigel, Schlieren and Wägital flysch do not presently point northward. No geologically meaningful interpretation of the amounts of rotation and transportation of these flysch units during their emplacement can be made from these remanent magnetiza-

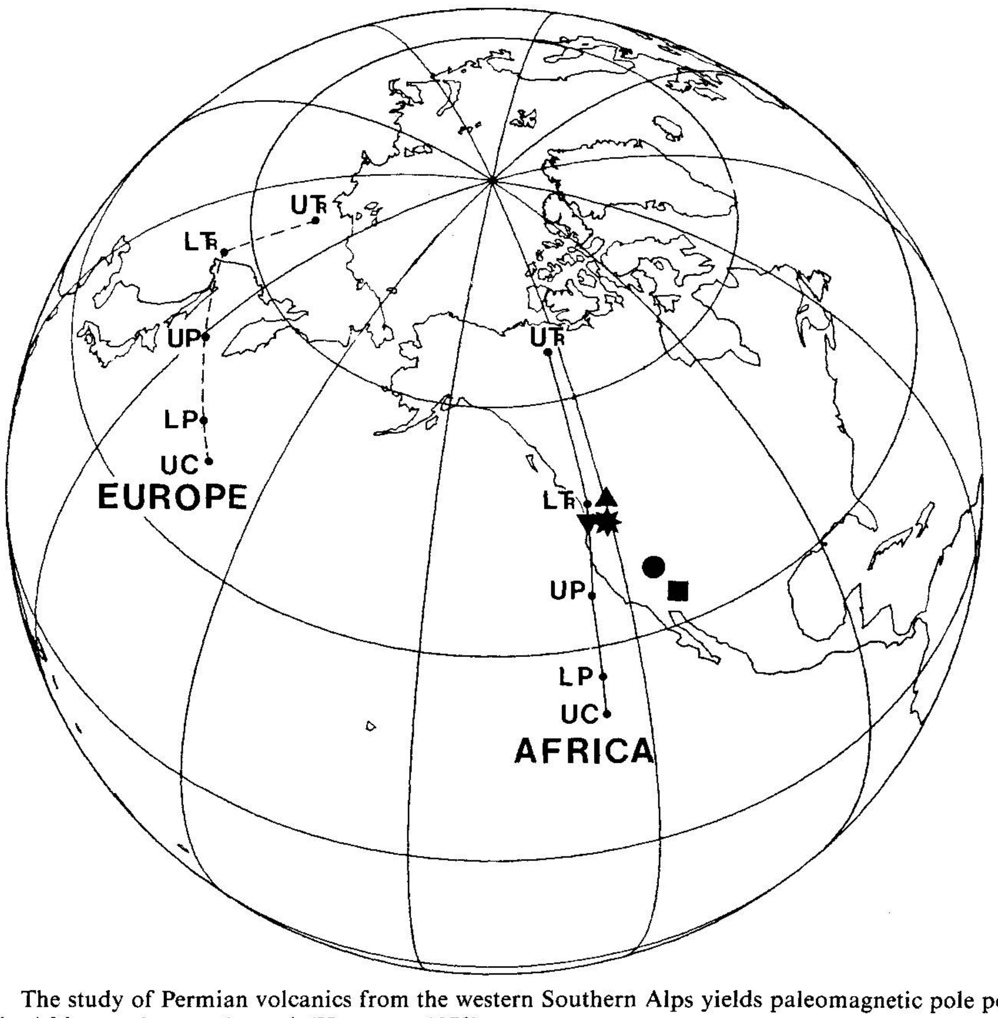

Figure 1 The study of Permian volcanics from the western Southern Alps yields paleomagnetic pole positions close to the African polar wander path (HEINIGER, 1978).

tions, which are most probably the result of very recent viscous re-magnetization (FREEMAN, 1979). The magnetic anisotropy of the flysch is comparable with paleocurrent directions inferred from macroscopic indicators such as flute casts (CHANNELL et al., in press; FREEMAN, 1979).

Magnetic anisotropy proved to be an important factor in deflecting the magnetization of the Bergell granite from its original direction (HELLER, 1971, 1973). The corrected directions indicated about 30° counterclockwise rotation of the Bergell Massif since the Miocene. Upper Tertiary directions, resulting from remagnetization following high temperature metamorphism, were measured in the central Alps; these also could be interpreted in terms of counterclockwise rotation of the Lepontine area (HELLER, 1977 a).

Paleomagnetic directions at 50 sites throughout Umbria have been analyzed. They indicate counterclockwise rotations relative to both European and African directions (LOWRIE and ALVAREZ, 1974, 1975). However, a distinct difference in directions is observed between sites in the northern part of Umbria and sites in the southern part. Between-site directional differences within each region are most readily explained by local differences in fold axis orientations. The overall north-south differences are compatible with oroclinal bending of the Umbrian arc. It is therefore unlikely that either the north or south of Umbria (or both) can be autochthonous. Thus, conclusions regarding the tectonic behavior of the Italian peninsula cannot be made directly from Umbrian paleomagnetic data (CHANNELL et al., 1978).

The paleomagnetic directions at sites in several thrust sheets in the Southern Apennines and Sicily have been compared with directions from the stable Iblean platform. These indicate various degrees of probable clockwise rotation during emplacement of the thrust sheets (CATALANO et al., 1976).

The rotation of Sardinia is known to have taken place in two phases. The later phase is well dated and was in the Miocene. The earlier phase has been investigated in Mesozoic carbonate rocks. The directions in Triassic and Jurassic limestones indicate counterclockwise rotations of amounts comparable to those found in Permian ignimbrites and redbeds, and suggest that the earlier phase of rotation occurred after the Late Jurassic (HORNER, 1979).

Paleomagnetic data from Italy, the Southern Alps and the Western Mediterranean have been integrated into a paleogeographic reconstruction involving impingement against the European plate of an Adriatic promontory to the African plate (CHANNELL and HORVATH, 1976; CHANNELL et al., in press).

MAGNETIC STRATIGRAPHY AND OCEANIC MAGNETIC ANOMALIES

The relative motions of the major global plates can be reconstructed by matching dated magnetic lineations on opposite sides of a spreading center. Of

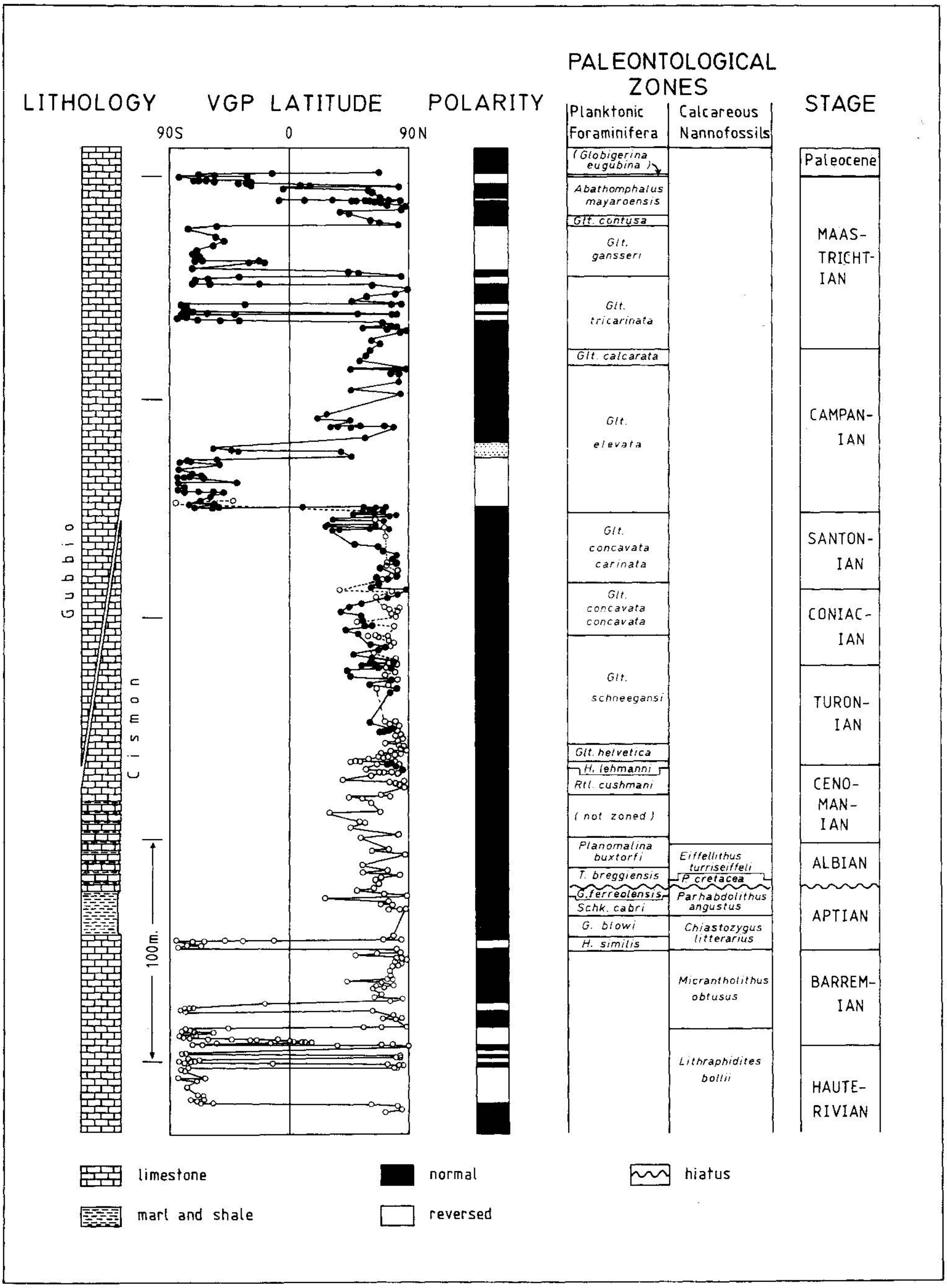

Figure 2 Magnetic stratigraphy studies in pelagic carbonate rocks at Gubbio (Umbria) and Cismon (S. Alps) reveal a record of the changing latitude of the virtual geomagnetic pole (VGP) from which the history of geomagnetic polarity, dated by planktonic foraminifera and calcareous nannofossils, has been derived for much of the Cretaceous (LOWRIE et al., in press).

great importance is the dating of the correlated anomalies. This can be achieved by comparison of the magnetic reversal sequence recorded by oceanic magnetic anomalies with that measured in dated continental rocks. In recent years Cretaceous pelagic carbonate rocks have given magnetic stratigraphies that closely match the oceanic polarity sequences and permit the anomalies to be tied to a biostratigraphic time scale (Fig. 2).

The Late Cretaceous polarity sequence found in the oceans is confirmed in every detail in the magnetic stratigraphy of the scaglia rossa pelagic limestone at Gubbio, Italy. The Cretaceous-Tertiary boundary determined from foraminifera falls in the reversed interval between anomalies 29 and 30 (LOWRIE and

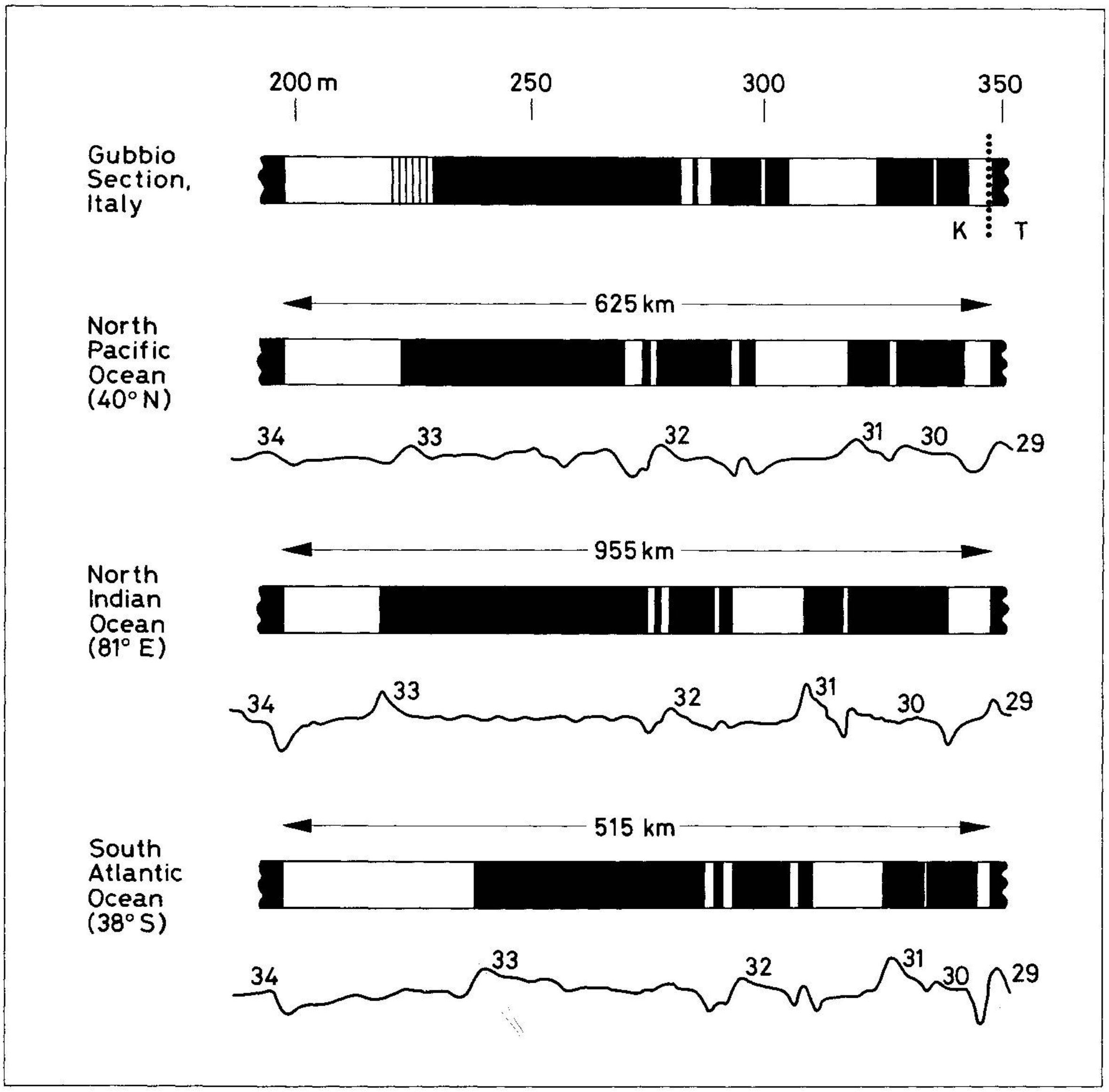

Figure 3 Oceanic magnetic anomalies on three long profiles in different oceanic basins give a sequence of geomagnetic polarity which can be correlated directly with the magnetic reversal sequence recorded in Late Cretaceous pelagic limestone on land (LOWRIE AND ALVAREZ, 1977a, 1977b).

ALVAREZ, 1977a, 1977b). The Cenozoic and Late Cretaceous anomaly sequence began with anomaly 34 which ended the Cretaceous magnetic quiet zone at the Santonian-Campanian boundary.

The Gubbio section has been established as a Late Cretaceous magnetostratigraphic type section (ALVAREZ et al., 1977) and its principal features have been confirmed in a scaglia rossa check section at Moria, Italy (ALVAREZ and LOWRIE, 1978).

The Cretaceous magnetic quiet zone began with anomaly MO of the Mesozoic anomalies sequence. The youngest of these anomalies have been found in a paleontologically dated section of the Biancone pelagic limestone at Cismon, in the Italian Southern Alps. The age of MO is Early Aptian, almost a full stage older than earlier indirect interpretations had estimated (CHANNELL et al., 1979). The Cismon dates of anomalies MO-M4 have been confirmed in check sections in the Fucoid marls and Majolica limestone in Umbria, Italy (LOWRIE et al., in press).

The correlations of the magnetic anomaly reversal scale and the magnetostratigraphic record in pelagic carbonate rocks is now confirmed for much of the Cretaceous (Fig. 3). Some additional reversals have been reported, but are still questionable because they have not yet been confirmed in check sections.

The beginning of the Mesozoic sequence was in the Late Jurassic. According to careful rock magnetic and paleomagnetic studies of limestones from the Frankenjura this sequence could not have begun before the end of the Malm-γ, in the middle Kimmeridgian (HELLER, 1977b, 1978). This is a full stage older than earlier presumed.

The calibration of the ages of the lineated Cenozoic and Mesozoic anomaly sequences alters the values of Cretaceous sea-floor spreading rates, but does not alter the fact that the Cretaceous quiet interval was characterized by rapid spreading of many of the world's oceans (LOWRIE, 1979).

The origin of oceanic magnetic anomalies has been investigated by several means. Analysis of magnetic properties of oceanic rocks indicates that the oceanic magnetic anomalies are not due to the uppermost layer of intensely magnetized basalts alone. Either this layer is much thicker than supposed, or a second layer-possibly the oceanic gabbro layer-contributes to marine magnetic anomalies (LOWRIE, 1977, 1979).

REFERENCES

ALVAREZ, W., and W. LOWRIE: Upper Cretaceous paleomagnetic stratigraphy at Moria (Umbrian Apennines, Italy): confirmation of the Gubbio section. Geophys. J. R. astr. Soc., *55*, 1–17, 1978.

ALVAREZ, W., M. A. ARTHUR, A. G. FISHER, W. LOWRIE, G. NAPOLEONE, I. PREMOLI SILVA and W. M. ROGGENTHEN: Upper Cretaceous-Paleocene magnetic stratigraphy at Gubbio, Italy. V. Type section for the Late Cretaceous-Paleocene geomagnetic time scale. Geol. Soc. Amer. Bull., *88*, 383–389, 1977.

CATALANO, R., J. E. T. CHANNELL, B. D'ARGENIO and G. NAPOLEONE: Mesozoic paleogeography of the Southern Apennines and Sicily. Mem. Soc. Geol. It., *15*, 95–118, 1976.

CHANNELL, J. E. T., and F. HORVATH: The African/Adriatic promontory as a palaeogeographical premise for Alpine orogeny and plate movements in the Carpatho-Balkan region. Tectonophysics, *35*, 71–101, 1976.

CHANNELL, J. E. T., W. LOWRIE, F. MEDIZZA and W. ALVAREZ: Paleomagnetism and tectonics in Umbria, Italy. Earth Planet. Sci. Lett., *39*, 199–210, 1978.

CHANNELL, J. E. T., W. LOWRIE and F. MEDIZZA: Middle and Early Cretaceous magnetic stratigraphy from the Cismon section, northern Italy. Earth Planet. Sci. Lett., *42*, 153–166, 1979.

CHANNELL, J. E. T., B. D'ARGENIO and F. HORVATH: Adria, the African promontory, in Mesozoic Mediterranean palaeogeography. Earth. Sci. Rev., in press.

CHANNELL, J. E. T., R. CATALANO, and B. D'ARGENIO: Paleomagnetism and deformation of the continental margin in Sicily. Tectonophysics, in press.

CHANNELL, J. E. T., F. HELLER, and J. VAN STUIJVENBERG: Magnetic anisotropy as an indicator of sedimentary fabric in the Gurnigel flysch, Eclogae Helv., in press.

FREEMAN, R.: Palaeo- and rock magnetic investigation fo the Gurnigel, Schlieren and Wagital flysch, Diploma thesis ETH Zürich, 1979.

HEINIGER, C.: Gesteins- und paläomagnetische Eigenschaften der Permischen Vulkanite aus den westlichen Südalpen. Doctoral thesis, ETH-Zürich, 1978.

HELLER, F.: Remanent magnetization of the Bergell granite. Z. Geophys., *37*, 557–571, 1971.

HELLER, F.: Magnetic anisotropy of granitic rocks of the Bergell Massif (Switzerland). Earth Planet. Sci. Lett., *20*, 180–188, 1973.

HELLER, F.: Palaeomagnetic data from the Western Lepontine Area (Central Alps). Schweiz. Min. Petr. Mitt., *57*, 135–143, 1977a.

HELLER, F.: Palaeomagnetism of Upper Jurassic limestones from southern Germany. J. Geophys., *42*, 475–488, 1977b.

HELLER, F.: Rock magnetic studies of Upper Jurassic limestones from southern Germany. J. Geophys., *44*, in press, 1978.

HORNER, F.: Paläo- und Gesteinsmagnetische Untersuchungen an Mesozoischen Karbonatgesteinen Sardiniens. Diploma thesis, ETH Zürich, 1979.

LOWRIE, W.: Intensity and direction of magnetization in oceanic basalts. J. Geol. Soc., *133*, 61–82, 1977.

LOWRIE, W.: Geomagnetic reversals and ocean crust magnetization. Deep Drilling Results in the Atlantic Ocean: Ocean Crust (AGU, Maurice Ewing Series, Vol. 2), 135–150. 1979.

LOWRIE, W., and W. ALVAREZ: Rotation of the Italian peninsula. Nature, *251*, 285–288, 1974.

LOWRIE, W., and W. ALVAREZ: Paleomagnetic evidence for the rotation of the Italian peninsula. J. Geophys. Res., *80*, 1579–1592.

LOWRIE, W., and W. ALVAREZ: Upper Cretaceous-Paleocene magnetic stratigraphy at Gubbio, Italy. III. Upper Cretaceous magnetic stratigraphy. Geol. Soc. Amer. Bul., *88*, 374–377, 1977a.

LOWRIE, W., and W. ALVAREZ: Late Cretaceous geomagnetic polarity sequence: detailed rock- and palaeomagnetic studies of the scaglia rossa limestone at Gubbio, Italy. Geophys. J. R. astr. Soc., *51*, 561–581, 197b.

LOWRIE, W., W. ALVAREZ, I. PREMOLI SILVA, and S. MONECHI: Lower Cretaceous magnetic stratigraphy in Umbrian pelagic carbonate rocks, Geophys. J., in press.

Manuscript received July 23, 1979