Magnetic susceptibility anisotropy as an indicator of sedimentary fabric in the Gurnigel Flysch

Autor(en): **Channell, James / Heller, Friedrich / Stuijvenberg, Jan van**

Objekttyp: **Article**

Zeitschrift: **Eclogae Geologicae Helvetiae**

Band (Jahr): **72 (1979)**

Heft 3

PDF erstellt am: **19.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-164861

Nutzungsbedingungen
Die ETH-Bibliothek ist Anbieterin der digitalisierten Zeitschriften. Sie besitzt keine Urheberrechte an den Inhalten der Zeitschriften. Die Rechte liegen in der Regel bei den Herausgebern.
Die auf der Plattform e-periodica veröffentlichten Dokumente stehen für nicht-kommerzielle Zwecke in Lehre und Forschung sowie für die private Nutzung frei zur Verfügung. Einzelne Dateien oder Ausdrucke aus diesem Angebot können zusammen mit diesen Nutzungsbedingungen und den korrekten Herkunftsbezeichnungen weitergegeben werden.
Das Veröffentlichen von Bildern in Print- und Online-Publikationen ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Die systematische Speicherung von Teilen des elektronischen Angebots auf anderen Servern bedarf ebenfalls des schriftlichen Einverständnisses der Rechteinhaber.

Haftungsausschluss
Alle Angaben erfolgen ohne Gewähr für Vollständigkeit oder Richtigkeit. Es wird keine Haftung übernommen für Schäden durch die Verwendung von Informationen aus diesem Online-Angebot oder durch das Fehlen von Informationen. Dies gilt auch für Inhalte Dritter, die über dieses Angebot zugänglich sind.

Ein Dienst der *ETH-Bibliothek*
ETH Zürich, Rämistrasse 101, 8092 Zürich, Schweiz, www.library.ethz.ch

http://www.e-periodica.ch

Eclogae geol. Helv.	Vol. 72/3	Pages 781-787	3 figures and 1 table in the text	Basle, November 1979

Magnetic susceptibility anisotropy as an indicator of sedimentary fabric in the Gurnigel Flysch[1]

By JAMES CHANNELL[2], FRIEDRICH HELLER[2] and JAN VAN STUIJVENBERG[3]

ABSTRACT

Magnetic susceptibility anisotropy in magnetite-bearing Gurnigel Flysch sandstones reflects the sedimentary settling of grains and in some cases the predominant current direction during deposition.

ZUSAMMENFASSUNG

Die Anisotropie der magnetischen Suszeptibilität in den magnetitführenden Sandsteinen des Gurnigel-Flysches widerspiegelt die sedimentäre Anordnung der Körner und in einigen Fällen die während der Sedimentation vorherrschende Strömungsrichtung.

RÉSUMÉ

L'anisotropie de susceptibilité magnétique dans les grès du Flysch du Gurnigel contenant de la magnétite reflète l'arrangement sédimentaire des grains et, dans quelques cas, la direction prédominante des courants pendant la sédimentation.

1. Introduction

The Gurnigel nappe is exposed between Lake Thun and Lake Geneva (Fig. 1). It consists of a 1200-1600 m thick series of Gurnigel Flysch, alternating sandstones and shales, deposited in a deep-water ("oceanic") environment. This sedimentation took place from Maastrichtian to Middle Eocene, probably in the South-Penninic-Ligurian realm (CARON 1976, MOREL 1978, VAN STUIJVENBERG 1979).

Samples for palaeomagnetic measurement were collected from fine-grained sandstones from four outcrops in the Gurnigel Flysch: Bärgli (Maastrichtian), Fayaux (Early Thanetian), Zollhaus (Early Ilerdian) and Falli Hölli (Early Ilerdian) (Fig. 1). Current directions from flute casts and other sedimentary textures were measured, after CROWELL (1955) and HSÜ (1960), by VAN STUIJVENBERG et al. (1976, Fayaux), VAN STUIJVENBERG (1979, Bärgli) and the authors (Zollhaus, Falli Hölli). The palaeocurrent directions, after simple tilt correction for dipping beds, are

---

[1] Publikation Nr. 241, Institut für Geophysik, ETHZ.

[2] Institut für Geophysik, ETH-Hönggerberg, CH-8093 Zürich.

[3] Institut de Géologie, Université de Fribourg, CH-1700 Fribourg.

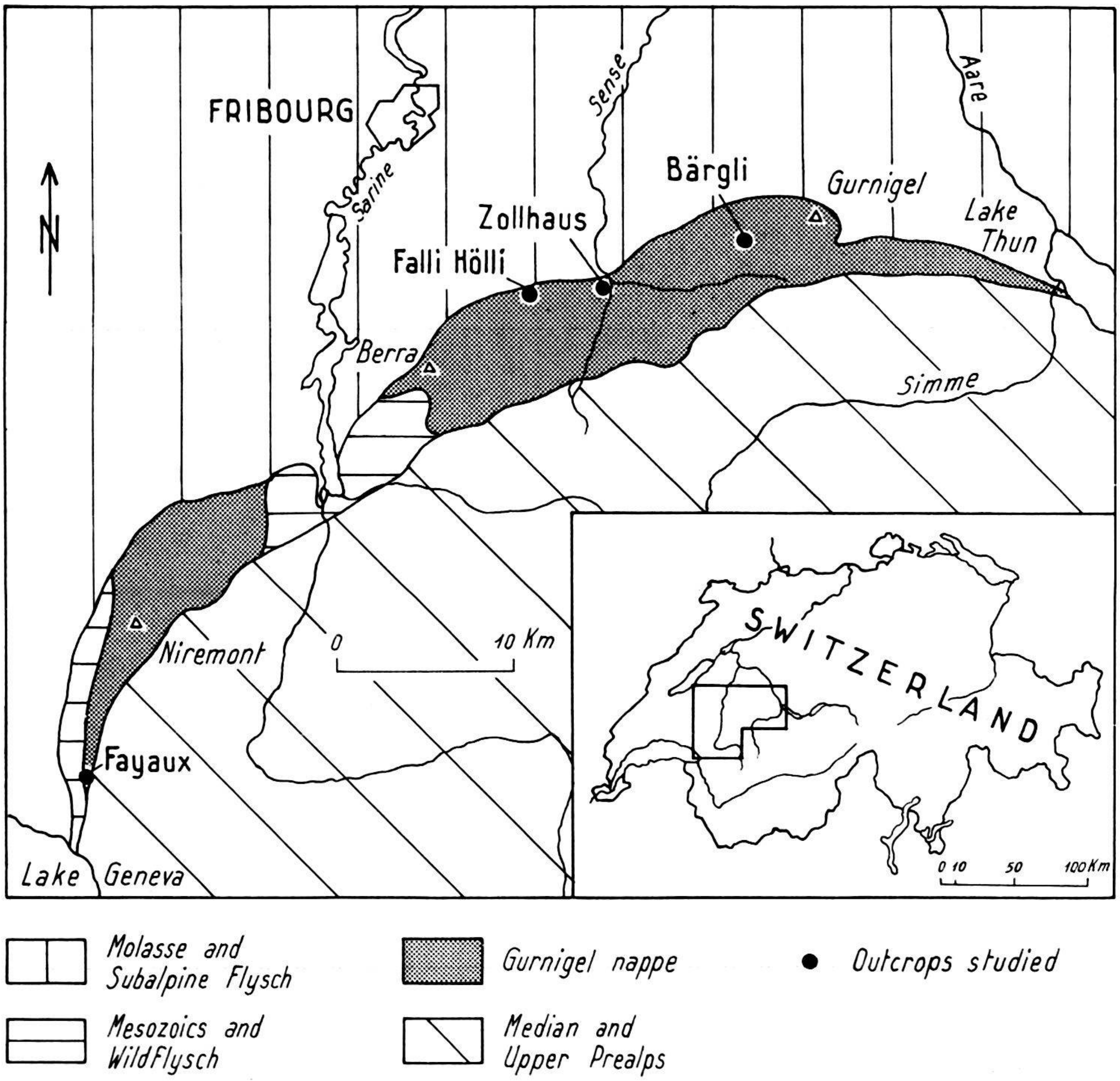


Fig. 1. Location of the Gurnigel nappe and outcrops studied.

generally from NW to SE (Fig. 2). As Figure 2 shows, there is often considerable scatter in the observed current directions. At Bärgli, an alternating secondary current direction from E to W is apparent.

2. Natural remanent magnetization

Whereas the coarse sandstones gave inconsistent remanent magnetization directions of very weak intensity, the fine-grained sandstones gave consistent magnetization directions not only within, but also between outcrops. The natural remanent magnetization (NRM) is weak ($\sim 10^{-4}$ A/m) and of low coercivity. The magnetization directions are close to the present earth's field direction before tectonic correction; and it has been shown (Channell & Heller 1980) by monitoring the build-up of viscous remanent magnetization (VRM) in the laboratory that the NRM can be accounted for by viscous acquisition during the present (Brunhes) epoch of normal geomagnetic polarity. Therefore the remanent magnetization cannot be associated with the time of deposition of the sediment and cannot give magnetostratigraphic or tectonic information.

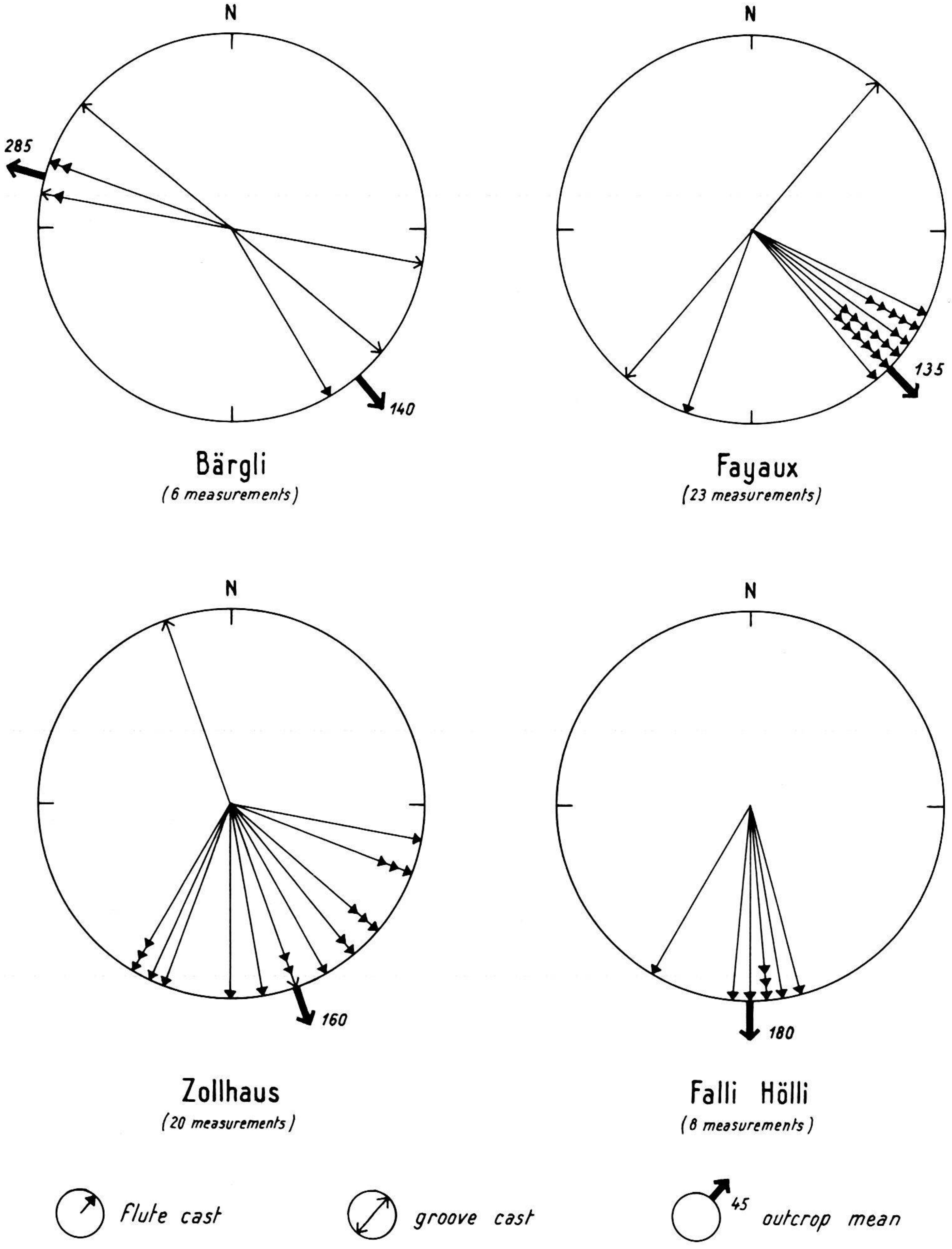
3. Introduction to susceptibility anisotropy

The sample magnetization (J_i) induced in an applied field (H_j) is given by the relationship: $J_i = \varkappa_{ij} H_j$, where the susceptibility term ($\varkappa_{ij}$) is a second-rank tensor, and can be geometrically represented by an ellipsoid with major axes $\varkappa_{max} > \varkappa_{int} > \varkappa_{min}$. Magnetite and haematite are the most common contributors to magnetic susceptibility in rocks. As the intrinsic susceptibility of magnetite is several orders of magnitude greater than that of haematite, magnetite (if present) will dominate the observed susceptibility ellipsoid. Magnetite has a cubic crystal structure such that the susceptibility is crystallographically anisotropic, with the maximum axis coinciding with the diagonal of the cube. However, as the grain shape of magnetite does not usually bear any consistent relationship to crystallographic axes, an assemblage of magnetite grains rarely shows preferential orientation of crystallographic axes, and therefore there is usually no anisotropy due to magnetocrystalline effects. On the other hand, the magnetic properties of magnetite-bearing rocks can be strongly anisotropic simply due to the preferred orientation of elongated grains. This shape anisotropy of magnetite is due to the fact that the demagnetizing field, generated by an applied field within an elongated grain is greater when the external field is perpendicular to the long axis of the grain than when it is parallel to the long axis. The demagnetizing field reduces the effectiveness of the applied field, and therefore the ease by which an elongated grain can be magnetized is maximum along its long axis.

There are various ways in which grains may become aligned according to shape, and hence give rise to a susceptibility anisotropy. When detrital grains are deposited, they tend to lie on their flat surfaces and there is a statistical alignment of small axes of grains perpendicular to bedding planes. Hence susceptibility minima tend to be oriented perpendicular to bedding. The orientation of long axes of magnetite grains may be due to the interplay between water currents and the geomagnetic field (REES 1961, HAMILTON 1967) or to the slope of the depositional surface (REES 1966). Laboratory experiments have shown that hydrodynamic grain orientation usually dominates any orientation effect of the geomagnetic field although in quiet conditions of deposition statistical orientation of long axes in the direction of the field is observed (REES 1961, HAMILTON & REES 1968).

4. Magnetic susceptibility measurements

Oriented cores (2.5 cm diameter) were collected from the four outcrops. Cylindrical samples 2.15 cm long, corresponding to the optimum length-to-diameter ratio of 0.86 for susceptibility measurements (SCRIBA & HELLER 1978), were sliced from


Bärgli
(6 measurements)

Fayaux
(23 measurements)

Zollhaus
(20 measurements)

Falli Hölli
(8 measurements)

Fig. 2. Flute cast directions, dip corrected.

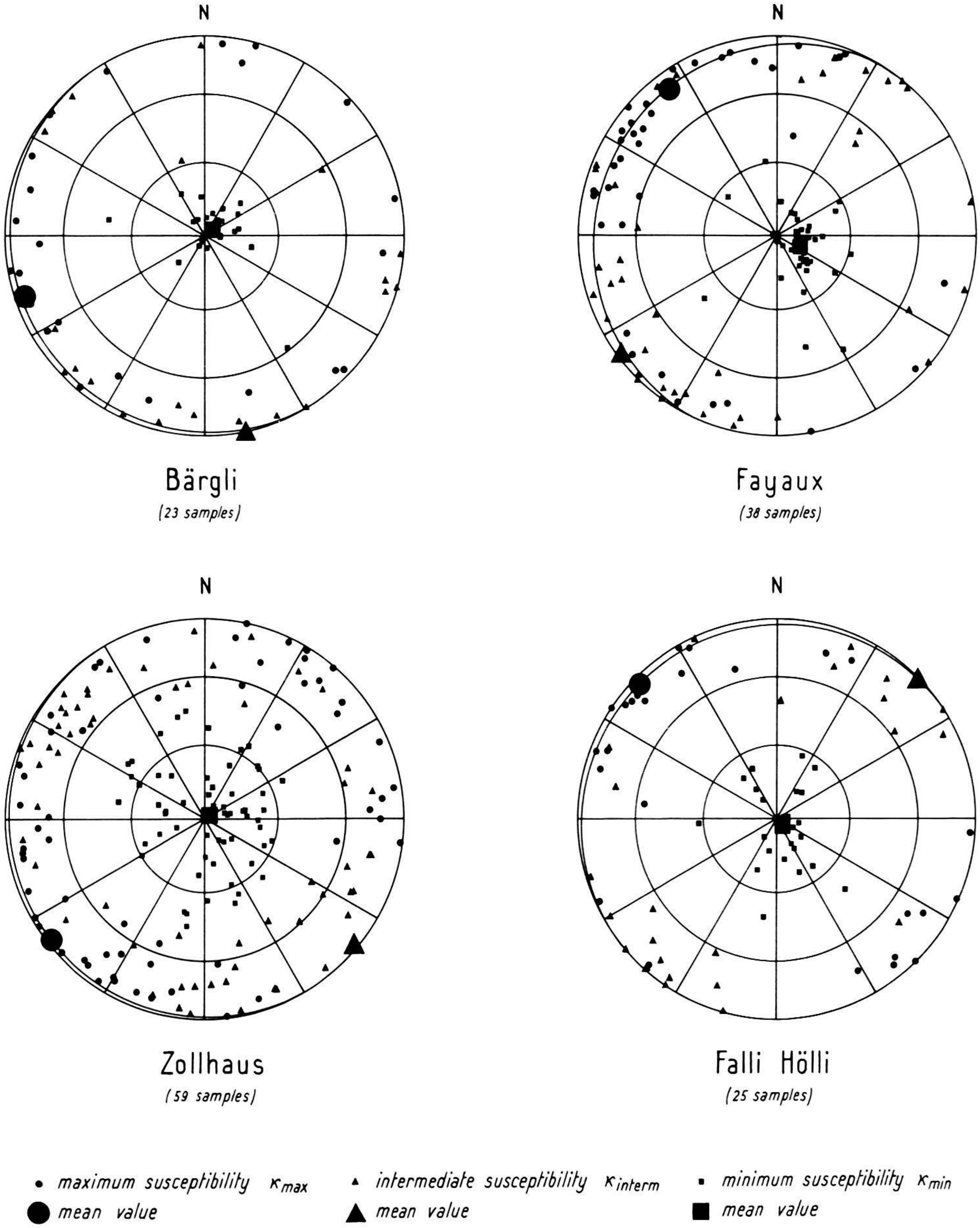


Fig. 3. Stereographic projection of susceptibility values, dip corrected.

the cores. Alternating field demagnetization of the samples, blocking temperature spectra and acquisition curves of isothermal remanence show that the principle magnetic mineral present is always magnetite (CHANNELL & HELLER 1980). Therefore, shape anisotropy of the assemblage of magnetite grains will dominate the shape and orientation of the susceptibility ellipsoid. The magnetic susceptibilities were measured using a ScT cryogenic magnetometer adapted for measurement of susceptibility anisotropy (SCRIBA & HELLER 1978). The orientations of the major axes of the susceptibility ellipsoids for each sample, after tilt correction for inclined beds, are given in Figure 3 and the mean values in the Table.

Table: *Azimuth, dip and angular standard deviation of mean principal axes of susceptibility.*

Outcrops		κ_{max}			κ_{int}			κ_{min}			$\frac{\kappa_{max}}{\kappa_{min}}$	$\frac{\kappa_{max}}{\kappa_{int}}$	$\frac{\kappa_{int}}{\kappa_{min}}$
(samples)		Az	Dip	Ψ63	Az	Dip	Ψ63	Az	Dip	Ψ63			
Bärgli	(23)	251.3	5.8	44.3	168.2	0.3	44.8	53.7	86.0	18.2	1.03	1.01	1.03
Falli Hölli	(25)	314.4	4.3	34.5	45.1	1.0	34.8	143.7	86.1	20.0	1.03	1.01	1.02
Fayaux	(38)	323.8	9.7	40.4	233.3	3.2	40.4	114.7	79.7	18.4	1.01	1.00	1.01
Zollhaus	(59)	232.0	2.8	41.0	129.9	2.9	45.2	49.5	87.6	26.6	1.02	1.01	1.01

The predominant feature is that the susceptibility minima are oriented perpendicular to the bedding planes, indicating that gravitational settling of grains has produced a statistical alignment of minimum elongation axes perpendicular to bedding. The maximum and intermediate susceptibility axes are generally more poorly defined. In other words, the ratio ($\varkappa_{max}/\varkappa_{int}$) is close to unity (Table) and the susceptibility ellipsoids are oblate (tending to be disc shaped). It should be noted that the shape of the overall susceptibility ellipsoid does not reflect the shape of the individual grains contributing to the susceptibility of a sample, however, statistical alignment of grain elongation axes can be observed.

In the case of *Zollhaus* (Fig. 3), the maxima and intermediate susceptibility axes are indistinguishable. This may be a result of the variable current direction indicated by the large scatter in flute cast orientations at this site (Fig. 2). The maximum and intermediate susceptibility axes of samples from *Falli Hölli, Fayaux* and *Bärgli* are more distinct (Fig. 3). At *Fayaux,* the maxima have similar orientation to the flute casts indicating preferred orientation of long axes of grains parallel to current direction. At *Falli Hölli,* a similar orientation of susceptibility maxima is found (Fig. 3), but this differs from the flute cast direction at this locality by 45° (Fig. 2). The explanation for this discrepancy is unclear. It should, however, be noted that the samples collected for anisotropy measurement came from the finer-grained material, and flute casts observed in the coarse base of beds may be recording water current directions which differ somewhat from those which affected the finer (upper) parts of the beds. In the case of *Bärgli,* where two distinct flute cast directions are apparent (Fig. 2), the number of anisotropy measurements was too small, and the scatter too large to establish a coincidence.

5. Conclusion

The susceptibility ellipsoids from the Gurnigel Flysch reflect the gravitational settling of magnetite grains as well as some statistical alignment of long axes of grains by hydrodynamic torque parallel to flow direction, as given by flute casts. A one-to-one relationship between flute cast orientations and orientation of susceptibility axes could not be established as the number of flute cast measurements is low and the susceptibility measurements rarely come from the same beds as the flute casts. However, as shown by VON RAD (1970) for graded and for cross-laminated sandlayers in Southern California, and by ARGENTON et al. (1975) for flysch in Southern France, the orientation of the maximum susceptibility axes appears to reflect the predominant current (flow) direction of the turbidites in a general way, and may provide an useful sedimentological tool where flute casts are rare or absent.

Acknowledgments

We are indebted to Bill Lowrie, Peter Homewood and Roy Freeman for valuable suggestions. Field assistance was given by René Morel, Wilfried Winkler and Daniel Cuennet. Françoise Mauroux typed the manuscript, and Georges Papaux drafted the figures. This work was supported by the Swiss National Science Foundation, Projects No. 2.1690/74 and 2.783-0.77, and by ETH funds.

REFERENCES

ARGENTON, H., BOBIER, C., & POLVÊCHE, J. (1975): *La mesure de l'anisotropie de susceptibilité magnétique dans les flyschs: applications à la recherche des directions des paléocourants.* - Sediment. Geol. *14*, 149-167.

CARON, C. (1976): *La nappe du Gurnigel dans les Préalpes.* - Eclogae geol. Helv. *69*/2, 297-308.

CHANNELL, J.E.T., & HELLER, F. (1980): *Magnetic Properties of the Gurnigel Flysch.* - J. Geophys. (in press).

CROWELL, J.C. (1955): *Directional current structures from the Prealpine Flysch, Switzerland.* - Bull. geol. Soc. Amer. *66*, 1351-1384.

HAMILTON, N. (1967): *The effect of magnetic and hydrodynamic control on the susceptibility anisotropy of redeposited silt.* - J. Geol. *75*, 738-743.

HAMILTON, N., & REES, A.I. (1968): *The use of magnetic fabric in palaeocurrent estimation.* In: RUNCORN, S.K. (Ed.): *Palaeogeophysics* (p. 445-464). - Academic Press, London.

HSÜ, K.J. (1960): *Paleocurrent structures and paleogeography of the Ultrahelvetic Flysch Basins, Switzerland.* - Bull. geol. Soc. Amer. *71*, 577-610.

MOREL, R. (1978): *Géologie du Massif du Niremont (Préalpes romandes) et de ses abords.* - Thesis Inst. Géol. Univ. Fribourg.

RAD, U. VON (1970): *Comparison between "magnetic" and sedimentary fabric in graded and cross-laminated sand layers, Southern California.* - Geol. Rdsch. *60*, 331-354.

REES, A.I. (1961): *The effect of water currents on the magnetic remanence and anisotropy of susceptibility of some sediments.* - Geophys. J. r. astron. Soc. *5*, 235-251.

— (1966): *The effect of depositional slopes on the anisotropy of magnetic susceptibility of laboratory deposited sand.* - J. Geol. *75*, 856-867.

SCRIBA, H., & HELLER, F. (1978): *Measurements of anisotropy of magnetic susceptibility using inductive magnetometers.* - J. Geophys. *44*, 341-352.

STUIJVENBERG, J. VAN (1979): *Geology of the Gurnigel area (Prealps, Switzerland).* - Matér. Carte géol. Suisse [n.s.] *151* (in press).

STUIJVENBERG, J. VAN, MOREL, R., & JAN DU CHÊNE, R. (1976): *Contribution à l'étude du flysch de la région des Fayaux (Préalpes externes vaudoises).* - Eclogae geol. Helv. *69*/2, 309-326.