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Post-folding characteristic remanent magnetization of the Upper Devonian Kostomłoty Beds in the Holy Cross Mts

ABSTRACT: Paleomagnetic investigations of the folded Upper Devonian limestones at Kostomłoty in the Holy Cross Mts, Central Poland, revealed the presence of characteristic remanent magnetization (*CHRM*). Its direction and space relationship to the fold structures indicate that *CHRM* was acquired not later than the Middle Carboniferous, superimposing the fold structures already existing in their recent shape.

INTRODUCTION

During last years, a new approach to tectogenesis of the Holy Cross Mts has been made. As a consequence, some fold structures previously regarded as Variscan were recognized or in many cases suspected to be of post-Cretaceous age (for detailed discussion *see* Kutek & Głazek 1972, Racki & Zapaśnik 1979). However, the idea that Variscan structures were disturbed in the Laramide cycle, well proved at the southwestern part of the Holy Cross Mts, stand still as an open question in the central part of this region where the Permo-Mesozoic cover upon the Paleozoic core is lacking.

In this paper it is shown how, with the help of paleomagnetic data, we are able to resolve the problem of dating of fold structures in geological time when conventional field methods are unsuccesful. An idea of the method applied here comes from Graham (*see* Irving 1964), who proposed a test, widely known among paleomagnetists to establish the stability of magnetization of folded rocks. According to Graham's method, the both limbs of a fold are sampled and directions of natural remanent magnetization (*NRM*) are measured. The test is positive, if

the reduction in scatter of the directions of *NRM* appears after correction for geological dip. The test is negative, if the scatter is smaller before correction. The latter result means that the investigated fold structure was remagnetized so the remanence is secondary in its origin. Though secondary, the *NRM* does not have to be unstable. The introduction of laboratory tests for stability showed that the secondary remanence may be persistent in geological time. Such a remanence is often called the characteristic remanent magnetization (*CHRM*). The time when *CHRM* was acquired must be established by comparision the *CHRM* direction with other paleomagnetic directions of well defined time of acquisition, considered as primary and taken from the stable platform, to which rocks under study belong. In this way, the time when the examined fold structure already existed may be established. The above method was applied to determine the age of the folds within the Kostomłoty Beds well exposed in the northern part of the Holy Cross Mts (*see* Text-fig. 1).

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FIELD AND LABORATORY METHODS

Ten independently orientated paleomagnetic hand samples have been taken from the folded limestones, belonging to the lower part of the Kostomłoty Beds (Frasnian) well exposed at the western end of the Kostomłoty Hills in the Laskowa Quarry (Text-figs 1—2). The folds axes are approximately horizontal and parallel to the axis of superior structure (that is Miedziana Góra syncline; *cf.* Text-fig. 1) trending WNW-ESE. Detailed analysis of the Kostomłoty Beds, its lithology and stratigraphy including, is given by Szulczewski (1971) and Przybyszewska (1973).

Six cubic specimens, cut from each sample, were demagnetized by means of alternating magnetic field. The peak amplitudes were increasing in steps to 600 Oe. After each step, components of the *NRM* vector of each specimen were measured with a spinner magnetometer *JR-3*. The results were averaged on the sample level and, afterwards, on the site level for a given demagnetization step (Text-fig. 3). In the case of sample *K10*, three additional specimens were subjected to thermal demagnetization in the Paleomagnetic Laboratoratory at the Department of Geophysics and Planetary Physics, University of Newcastle upon Tyne, which

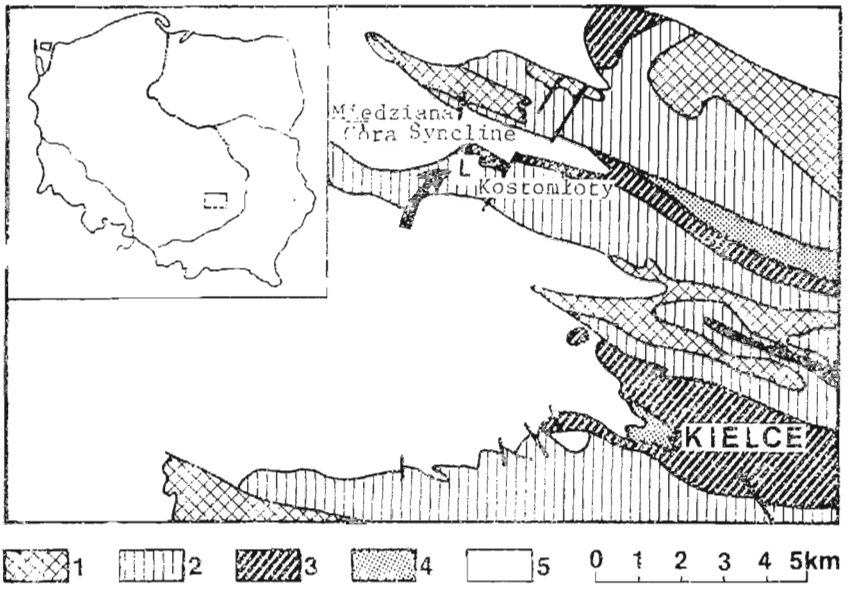

Fig. 1. Geological sketch map of the north-western part of the Holy Cross Mts (*after* Szulczewski 1971, Text-fig. 1; *simplified*), to show location of the Laskowa Quarry (**L**) at Kostomłoty village

1 **Cambrian, Ordovician and Silurian,** *2* **Lower and Middle Devonian,** *3* **Upper Devonian,** *4* **Lower Carboniferous,** *5* **post-Variscan cover (Zechstein — Upper Cretaceous)**

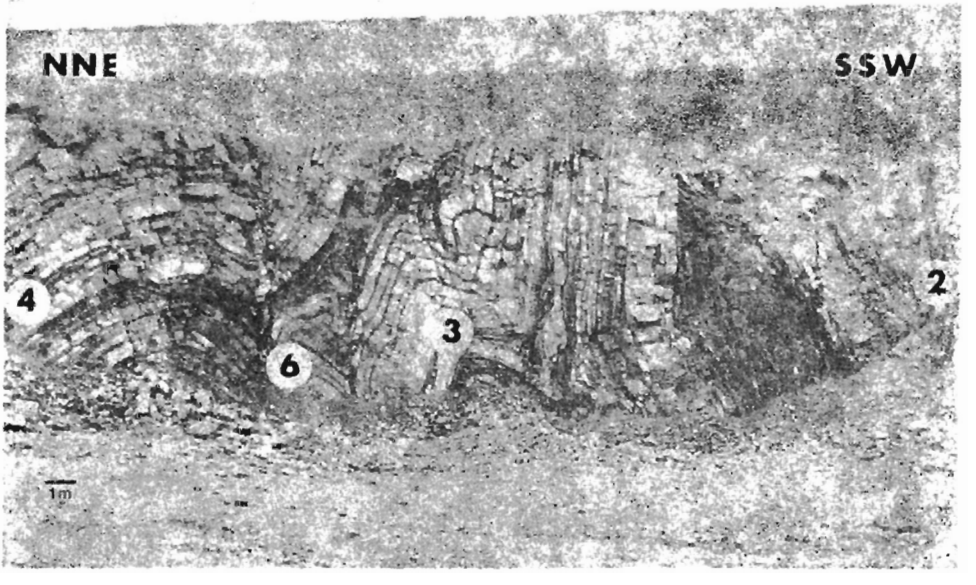

Fig. 2. Fold structures in the Laskowa Quarry at Kostomłoty; some sampling places are indicated

yielded the same results, in the range of experimental error, as the alternating field cleaning method.

RESULTS

The mean resultant vectors of *NRM* are presented (Text-fig. 3) in two coordinate systems (*cf.* Schmidt 1974):

(*i*) ancient coordinate system, in which the x, y plane coincides with the primary surface of deposition
(*ii*) site coordinate system, in which the x, y plane is horizontal.

The x axis points north in the both above systems.

Due to the fact that the *NRM* vector does not change its direction during magnetic cleaning, it may be considered as stable (for details *see* Irving 1964). In accordance with the criterion of Irving, the *NRM* direction of 200 Oe level should be chosen as representative of the *CHRM*. The direction of *CHRM* is determined in the site coordinate system, in which coincidence ($a = 8°$) is much better then in ancient coordinates ($a = 32°$), where a is the radius of the circle of confidence in which the true mean of population of N directions lies with a probability of 95%.

H [Oe]	In [nT]	Site coordinates					Ancient coordinates				
		I	D	α_{95}	L	F	I	D	α_{95}	L	F
-	1.5	35	234	9.5	30W	6S	37	258	32.1	47W	9N
150	1.1	17	227	7.9	29W	18S	27	243	30.8	42W	4S
200	1.0	14	225	7.9	29W	20S	25	241	32.0	41W	6S
300	0.6	12	223	8.3	27W	22S	24	239	33.1	39W	8S
400	0.3	12	221	9.3	25W	24S	25	235	-	36W	9S
600	0.3	13	222	10.1	26W	23S	25	237	-	37W	8S

Fig. 3. Results of demagnetization of the Lower Frasnian limestones from Kostomłoty
H peak intensity of alternating magnetic field, *In* intensity of NRM vector, *I* inclination, *D* declination, α_{95} radius of the circle of confidence, *L* longitude of paleomagnetic pole, *F* latitude of paleomagnetic pole

The convergence in the site coordinate system means that *CHRM* direction does not depend on the geometry of fold structures (Graham's test is negative); therefore, the fold structures must have already existed when the *CHRM* was acquired.

The geological time of the acquisition of *CHRM* may be established indirectly by comparing the direction of *CHRM* with the so-called expected paleomagnetic mean directions (*cf.* Małkowski 1975). For the aim of this work the expec-

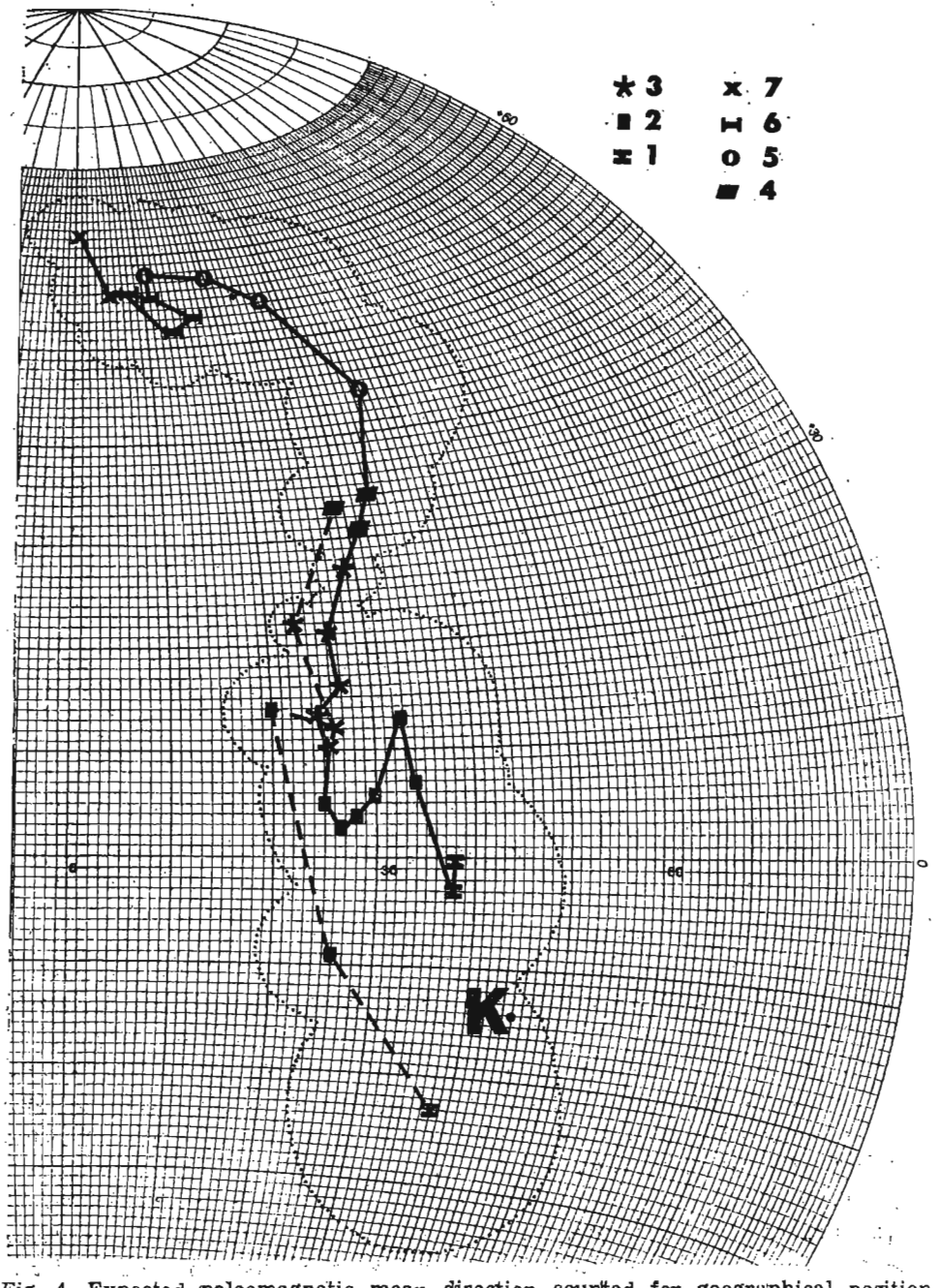

Fig. 4. Expected paleomagnetic mean direction counted for geographical position of Kielce in the Holy Cross Mts (*cf.* Text-fig. 1)

Solid line — path based on the data given by Irving (1977, simplified), *broken line* — path based mainly on the data from the Russian platform (given by "Paleomagnetic direction and paleomagnetic poles. Data from USSR", published by the Sov. Geoph. Comm. Acad. Sciences USSR, 1971, 1973, 1975, 1979). Amount of points, describing every period, determine degree of the equal part division of this period [with exception of Russian data for which only Middle (Baskhirian and Moscovian stages) and Upper Carboniferous (Uralian stage) directions are presented, whereas Lower Carboniferous (Tournaisian — Namurian stages) are rejected as unreliable]. Dotted line is a border of a_{95} area, summarized for the both paths. Declinations are given by meridians, inclinations by parallels of latitude. Letter **K** shows Kostomloty CHRM direction. Equal area projection

1 Devonian, **2** Carboniferous, **3** Permian, **4** Triassic **5** Jurassic, **6** Cretaceous, **7** Tertiary

ted mean directions were calculated on the ground of axial geocentric dipole hypothesis, along geochronological time scale for the Holy Cross Mts latitude and longitude. The base of calculations were paleomagnetic pole positions from the Russian platform, published up to 1979. A few poles from pre-Alpine stable area were also taken. Paleomagnetic poles based on undemagnetized samples were rejected.

Comparatively, the pole positions given by Irving (1977) for northern Eurasia were recounted for the geographical position of the Holy Cross area. The juxtaposition of the expected mean directions (Text-fig. 4) and the *CHRM* direction revealed at Kostomłoty leads to conclusion, that the *CHRM* is of the Upper Devonian or Middle Carboniferous age. A conformability with the former is obtained after correction for the Permian 25° N dip, whereas a good agreement with the latter is achieved after turning the fold structures of the Kostomłoty Beds in horizontal plane by about 20° north.

Generally pre-Permian age of the *CHRM* is also confirmed by the data of McElhinny (1973) and Van der Voo (1974). The reversed polarity of the *CHRM* at Kostomłoty is an additional fact to support its Late Paleozoic age, as opposite to contemporary polarity was dominated during that period. Therefore, the Kostomłoty fold structures should be considered as a result of the Variscan tectonic movements.

DISCUSSION AND GENERAL REMARKS

Theoretically it is possible that the *CHRM* direction in the investigated area is of the Laramide age. If so, we have to accept that after post-Cretaceous remagnetization the Kostomłoty fold structures were turned en block by almost 90° around the horizontal axis. Apart from the low probability of finding the *CHRM* vector along another expected direction, there are no geological or geophysical evidences for such tectonic movements, which should affect also the Miedziana Góra syncline, as the Kostomłoty structures are their integral part.

There are other paleomagnetic results, which confirm the existence of pre-Laramide fold structures. As it is, fold structures in the Jaźwica Quarry (*see* Racki & Zapaśnik 1979) were remagnetized in their contemporary shape about 170 mln years ago (*cf.* Irving 1977), what have been ascertained by the Author (Lewandowski *in preparation*). Małkowski (1975) found the folded Ordovician clays at Bardo (eastern part of Holy Cross Mts) as remagnetized in the Triassic. If we would recognized those fold structures and directions of their *CHRM* as being of post-Cretaceous age, we should conclude, on the base of the above considerations that the Holy Cross Mts have quite different tectonic history than it is supposed today.

The method described in this paper can be applied, in suitable cases, to other tectonic problems, as fold relaxations (*cf.* Jaroszewski 1974, p. 220), interferences of phases of tectonic movements (*cf.* Bonhommet, Cobbold & Perroud 1980) or rejuvenating of fold structures (*i.e.* in the Chęciny anticline in the southwestern margin of the Holy Cross Mts, *see* Kutek & Głazek 1972), although the accuracy of time determination of such events is still not very precise (*cf. also* Van der Voo & Channell 1980).

The results presented here show that the fold structures in the Upper Devonian Kostomłoty Beds were remagnetized not later than the Middle Carboniferous. At the time of remagnetization, the investigated fold structures existed in their present shape, so they should be considered as an effect solely of the Variscan diastrophic cycle.

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WTÓRNA, STABILNA POZOSTAŁOŚĆ MAGNETYCZNA W WAPIENIACH FRANU W KOSTOMŁOTACH

(Streszczenie)

Przedmiotem pracy jest próba określenia czasu fałdowania wapieni franu w Kostomłotach koło Kielce (*patrz* fig. 1—2) na podstawie paleomagnetycznego testu Grahama.

Standardowe badania laboratoryjne (rozmagnesowanie polem zmiennym, *patrz* fig. 3) dziesięciu prób, pobranych w kamieniołomie „Laskowa" z systemu fałdów zbudowanych z wapieni franu, pozwoliły określić składowe wektorów stabilnej pozostałości magnetycznej. Stwierdzono, że pozycja przestrzenna średniego wektora pozostałości magnetycznej każdej z prób nie zależy od geometrii fałdów, co oznacza, że pozostałość magnetyczna ma genezę wtórną i powstałą później, aniżeli badane formy fałdowe.

Czas przemagnesowania badanych wapieni w fałdach kostomłockich określono poprzez porównanie kierunku wypadkowego wektora stabilnej pozostałości magnetycznej (tzw. charakterystyczna pozostałość magnetyczna — *CHRM*) z drogą wędrówki średniego wektora paleomagnetycznego, obliczoną dla współrzędnych geograficznych Kielc na podstawie skatalogowanych paleobiegunów magnetycznych obszaru Europy platformowej (*patrz* fig. 4).

Wyniki analizy paleomagnetycznej prowadzą do wniosku, że fałdy kostomłockie powstały w waryscyjskim cyklu diastroficznym i nie zmieniły swojego kształtu do dziś.