Late Variscan tectonothermal history of the Holy Cross Mts. (central Poland), as revealed by integrated palaeomagnetic and 1-D basin modelling study

J. Grabowski[1], M.Narkiewicz[1], R. Szaniawski[2], M. Resak[3], R. Littke[3]

[1]Polish Geological Institute, Rakowiecka 4, 00-975 Warszawa, Poland, jacek.grabowski@pgi.gov.pl; marek.narkiewicz@pgi.gov.pl

[2]Institute of Geophysics, Polish Academy of Sciences, Księcia Janusza 64, 01-452 Warszawa, Poland, rafsz@igf.edu.pl

[3]Institute of Geology and Geochemistry of Petroleum and Coal, RWTH Aachen, Lochnerstr. 4-20, 52056 Aachen, Germany

1. Setting and aim of the study

Classical outcrops of the Holy Cross Mts (HCM) in Poland are among a few areas in Central Europe exposing a complete succession of Phanerozoic strata. The Palaeozoic core of the HCM consists of two Early Palaeozoic tectonostratigraphic units - southern (Małopolska) and northern (Łysogóry), separated by the Holy Cross Fault. During the Devonian-Carboniferous the HCM area was located in the foreland of the Variscan Orogen (Fig. 1.1). In the Permian-Mesozoic it became incorporated into the Mid-Polish Trough which was inverted near the Cretaceous-Paleocene boundary to become the Mid-Polish Swell. The Paleocene to recent erosion removed thick Permian-Mesozoic sediments (Fig. 1.2).
The aim of our study is to contribute to a better understanding of burial and thermal history of the HCM using available palaeomagnetic (investigations in progress) and palaeothermal data. Sections situated in areas of contrasting thermal histories were chosen for integrated palaeomagnetic investigations and thermal modelling.

Fig. 1.1.

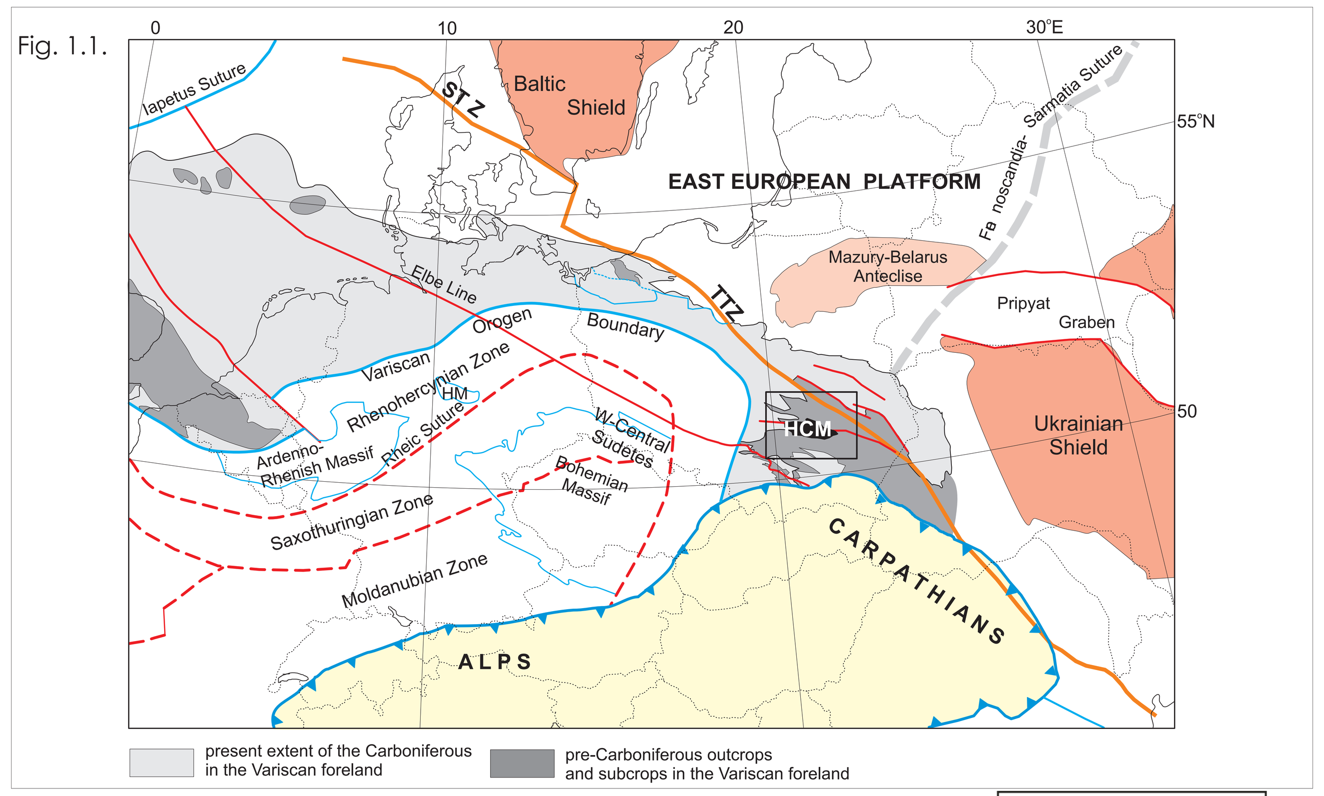
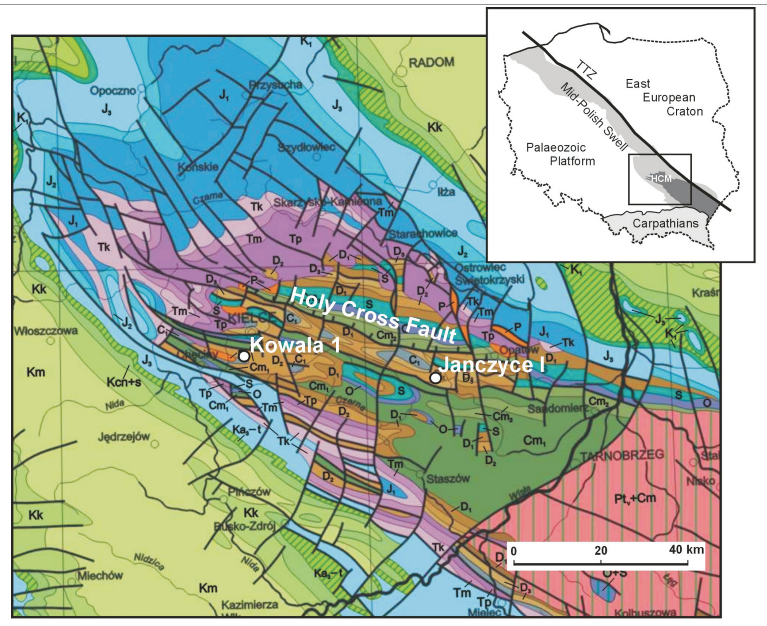


Fig. 1.2.



2. Palaeomagnetism

Paleomagnetic investigations of Middle - Upper Devonian carbonates in the HCM revealed presence of two secondary components A and B, carried by magnetite. Both components might be dated in relation to folding by fold

Component A

before tectonic correction | after tectonic correction

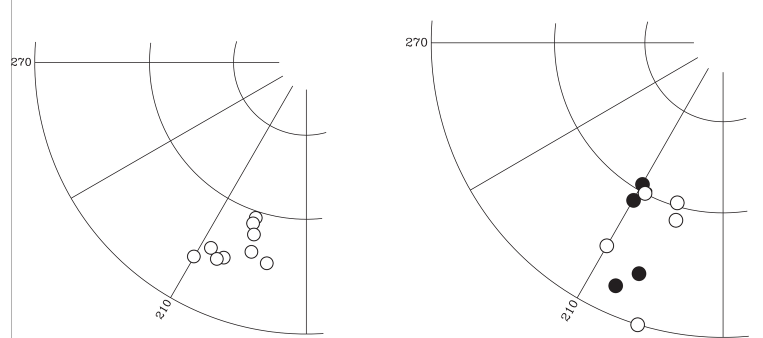


Fig. 2.1. Stereographic projection of locality mean component A, *in situ* (left) and after 100% tectonic correction (right). Open (black) dots indicate upper (lower) hemisphere projection. Note better clustering in the *in situ* position.

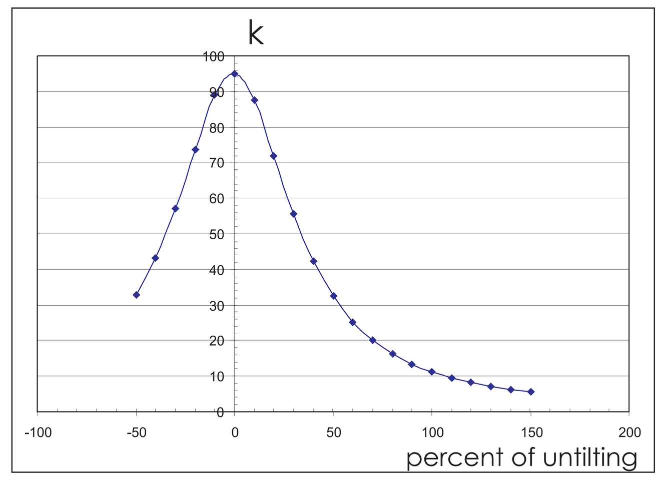


Fig. 2.2. Fold test for component A.Precision parameter (k) vs. percent of untilting. Best clustering at 0%, which indicates post-folding age of component A.

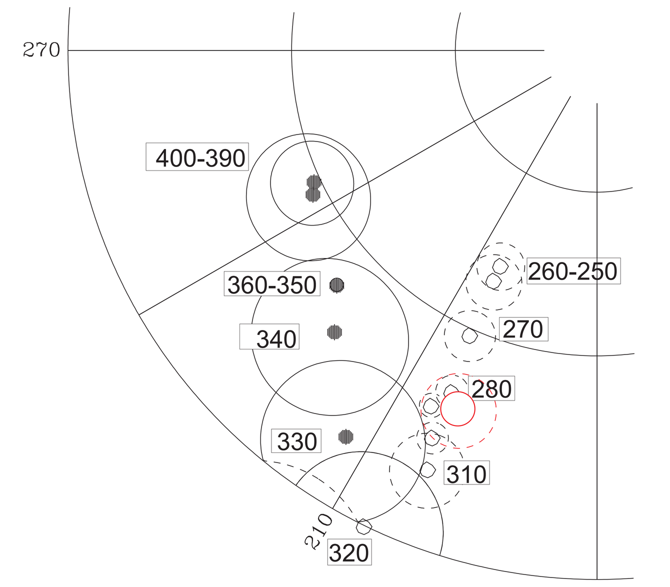


Fig. 2.3. Component A (in red) against of reference paleodirections for the HCM (in Ma), calculated from the apparent polar wander path (APWP) for the European plate in the Late Paleozoic (after Torsvik & Cocks 2005). The mean age of component A might be estimated as 300 - 280 Ma (Early Permian).
The mean direction of component A:
D/I = 200/-18, α_{95} = 5.3, k = 95.1, N =9, where:
D - declination, I - inclination, a95, k - Fisher statistics parameters, N - number of localities.

Component B

before tectonic correction | after tectonic correction

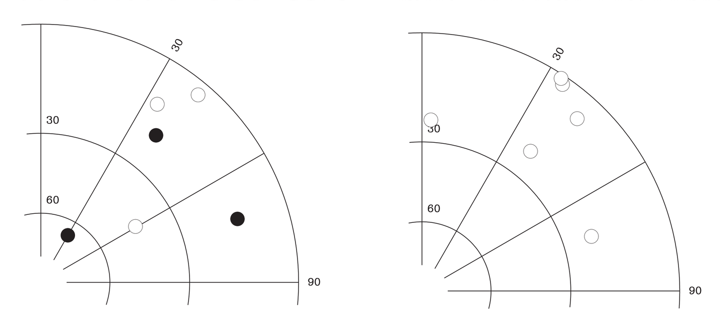


Fig. 2.4. Stereographic projection of locality mean component B, *in situ* (left) and after 100% tectonic correction (right). Open (black) dots indicate upper (lower) hemisphere projection. Note slightly better clustering after tectonic correction. Dispersion might be explained by vertical axis tectonic rotations, that took place after acquisition of the component B.

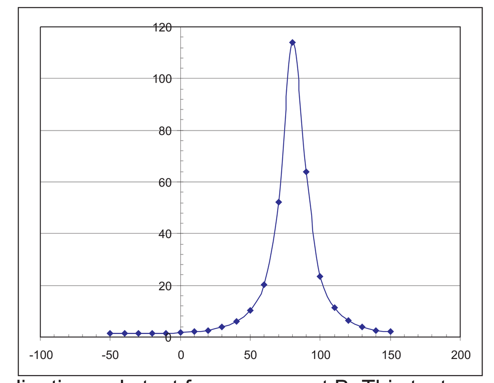


Fig. 2.6. Inclination-only test for component B. This test disregards effects of local tectonic rotations. Early sub-folding age of component B is confirmed: best precision of inclination estimation is after 82% tectonic correction.

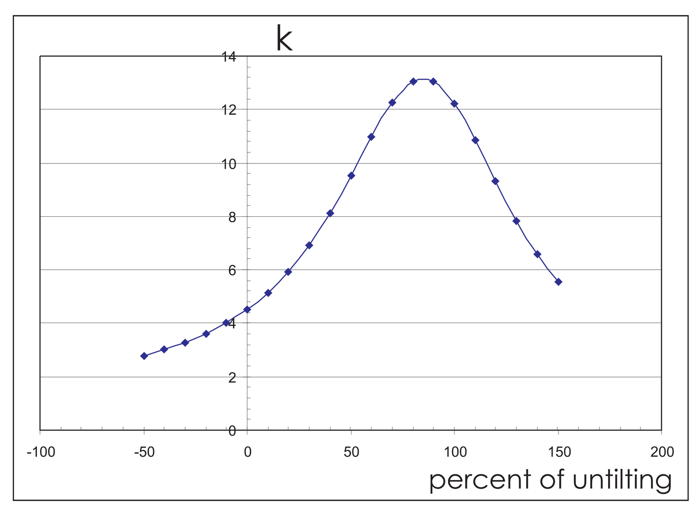


Fig. 2.5. Fold test for component A.Precision parameter (k) vs. percent of untilting. Best clustering at 85%, which might indicate early syn-folding age of component B.

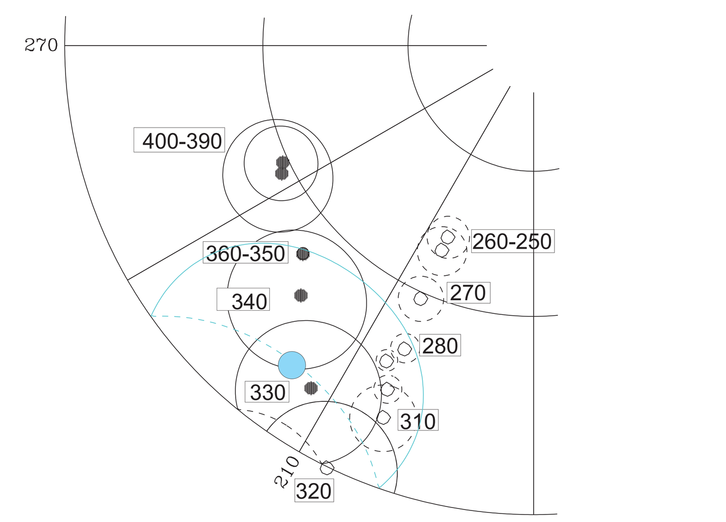


Fig. 2.7. Component B (in blue) against of reference paleodirections for the HCM (in Ma), calculated from the APWP for the European plate in the Late Paleozoic (after Torsvik & Cocks 2005). The mean age of component B might be estimated as 330 Ma (Late Visean), although confidence oval is fairly large (between 350 and 315 Ma).
The mean direction of component B:
D/I = 37/-9, α_{95} = 19.3, k = 13.1, N =6,

3. Palaeomagnetism vs. thermal alteration

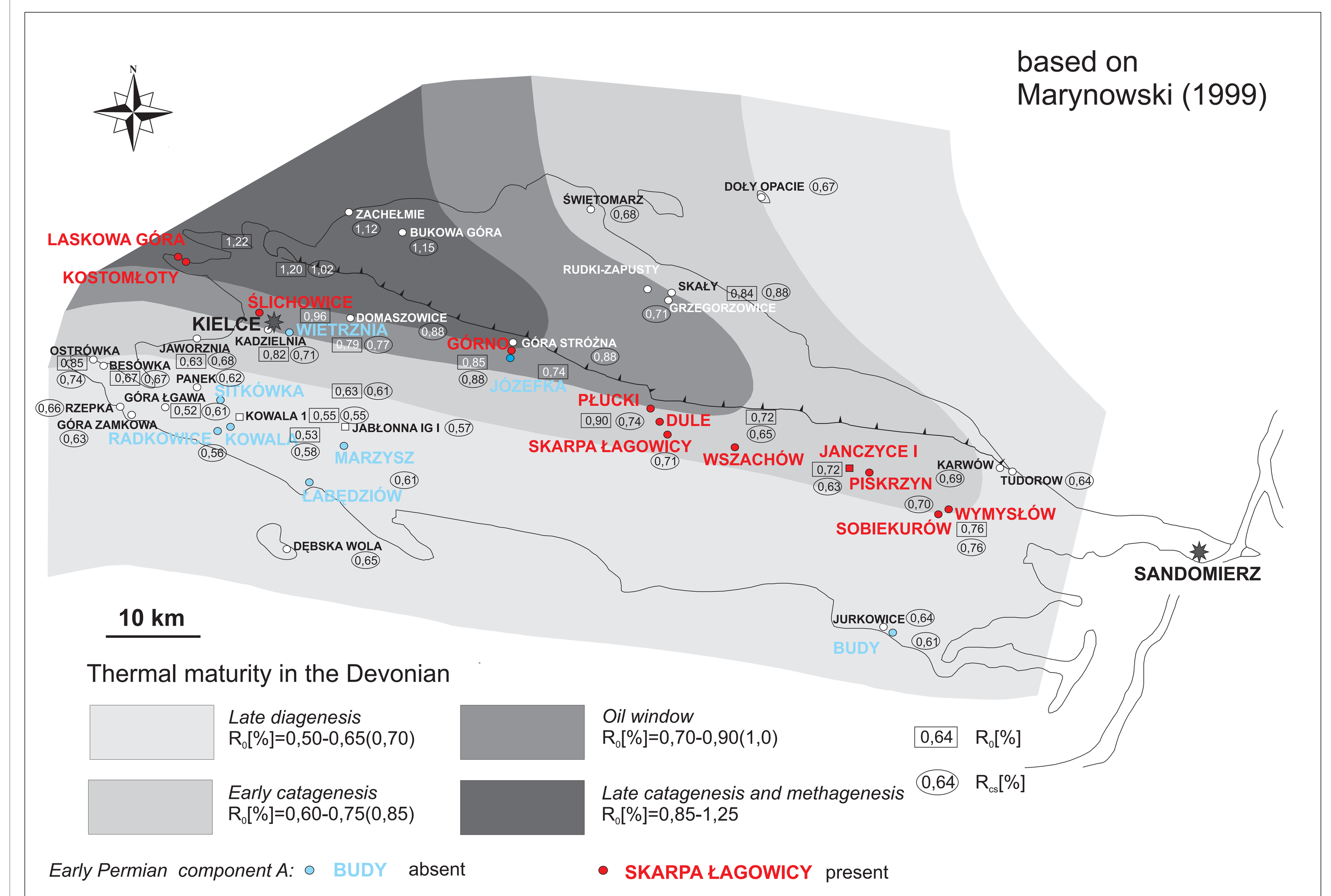


Fig. 3.1. Thermal maturity map of the HCM and hitherto paleomagnetically investigated Devonian localities in the southern region. In red - localities where component A is present as the only or dominant component of magnetization. In blue: localities where where component A is absent and component B is the only ancient magnetization. Note that component A is confined to the zone of increased thermal alterations close to the Holy Cross Dislocation. This indicates that acquisition of component A must be somehow related to Variscan thermal event. The most likely explanation is that remagnetization occurred during cooling of the rocks.

Thermal maturity of the Devonian strata was studied basing on vitrinite reflectance and biomarkers (see the map on the left) and conodont CAI. The data consistently point to maximum values related to the N and particularly NW part of the southern region. At the same time, the maturity in the Upper Permian-Triassic is uniformly low (VR ~0.6 %) around the Palaeozoic HCM core. This indicates that the pre-latest Permian heat flow could have been elevated, particularly along the W part of the HC Fault. This conclusion is consistent with observations of Carboniferous-Early Permian hydrothermal activity: dolomitization, polymetallic mineralization and hydrothermal karst. Meso-Cenozoic thermal conditions were controlled mainly by subsidence under low heat flow regime. The latter observation is consistent with both geological data and 1-D modelling results (see section 4).

4. Palaeomagnetism vs. 1-D modelling

Age [Ma]

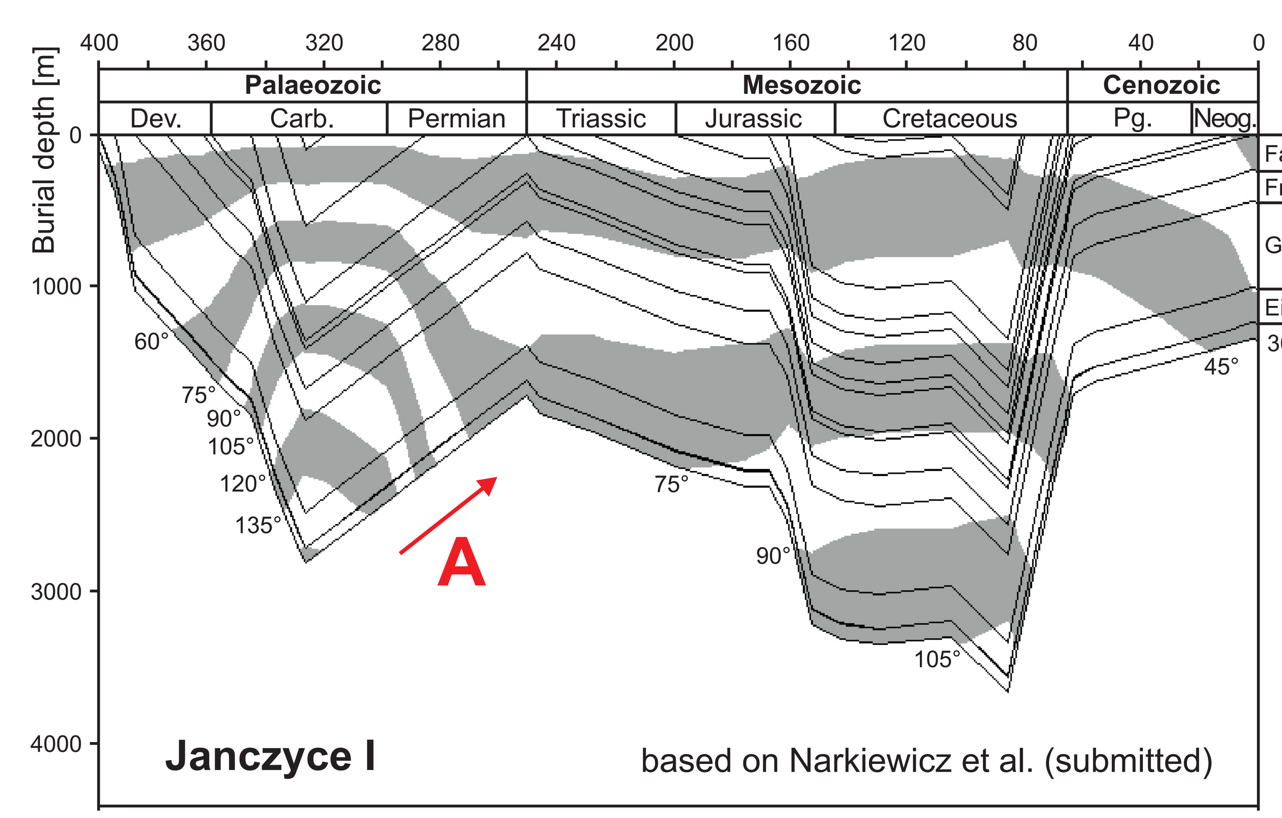


Fig. 4.1. Janczyce I well (see Fig. 1.2.). represents local Early Carboniferous depocenter and a higher magnitude of the Late Carboniferous uplift and erosion (ca. 1 000m). It is also located in the area of higher Variscan heat flow (see section 3). Results of thermal modelling suggest L. Carboniferous - Permian cooling from 130-150°C to 75-100°C which could lead to acquisition of the component A, which almost completely reset the older component B.

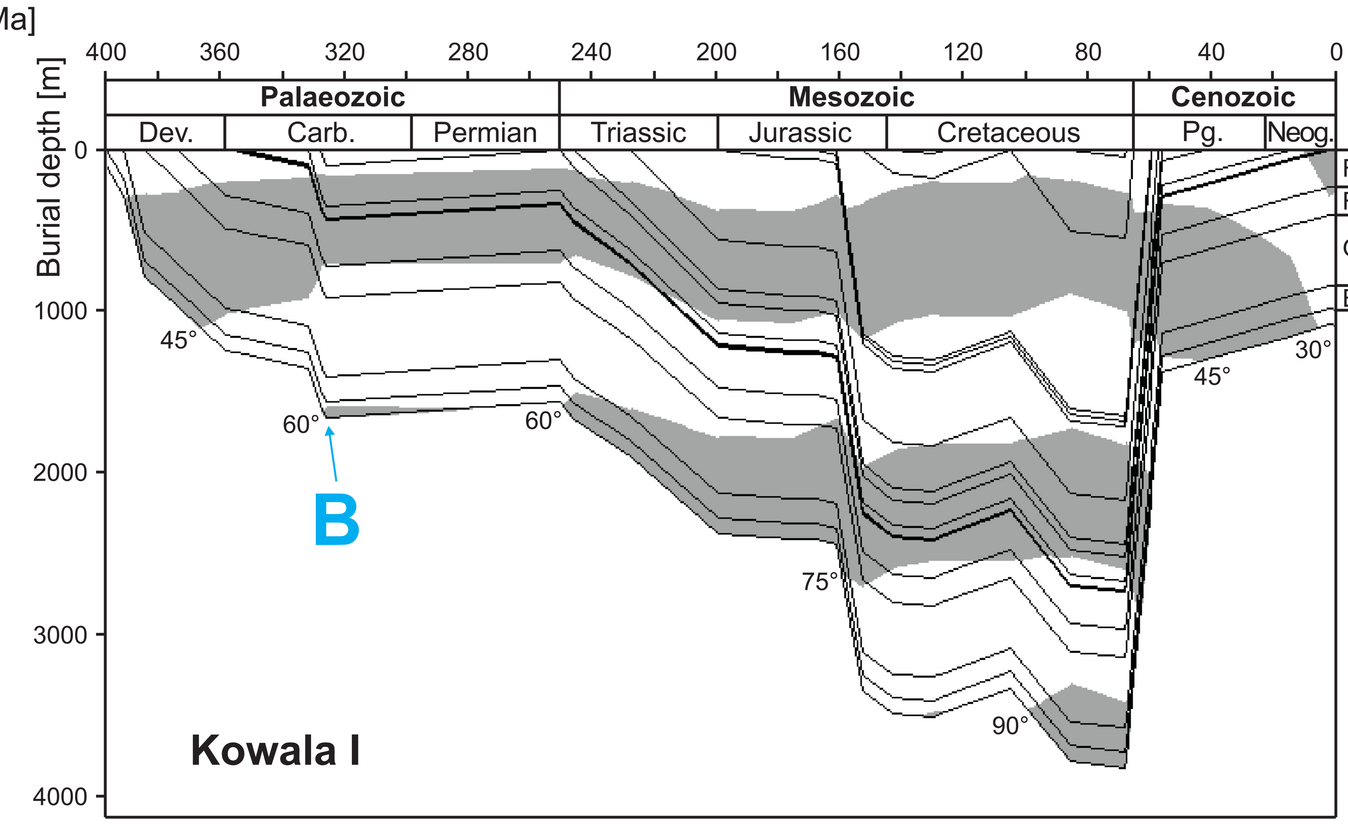


Fig. 4.2. The Kowala ! section (see Fig. 1.2 for location) represents a local palaeohigh with less Devonian-Carboniferous subsidence and smaller amplitude of the Variscan inversion. Lower magnitude of the max. burial and lower heat flow regime led to moderate burial temperatures and lack of cooling effect. This facilitated preservation of the early synfolding magnetization (component B) in the Early Carboniferous, during max. burial of Devonian strata.

5. Conclusions

There is a very good agreement between paleomagnetic - paleothermal data and thermal modelling results for Devonian of southern part of the HCM. Two ancient components (A and B) are secondary and reside in magnetite. Post-folding component A of Early Permian age, is confined to the area of elevated Variscan heat flow and higher thermal maturities. It originated most probably as thermoviscuous magnetization acquired during post-Variscan cooling and uplift. The process is easily recognized in thermal modeling - its magnitude amounted to ca. 1 000 m uplift and cooling from 130-150°C to 75-100°C. Early syn-folding component B of Early Carboniferous (Visean?) age was preserved in the area less thermally altered. Its probably Visean age corresponds well with presumed onset of folding in the HCM. Thermal modelling results suggest that it might have been

6. References

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