GEOLOGICA CARPATHICA, 54, 5, BRATISLAVA, OCTOBER 2003
281–297

METAMORPHOSED CARBONATES OF KRKONOŠE MOUNTAINS AND PALEOZOIC EVOLUTION OF SUDETIC TERRANES (NE BOHEMIA, CZECH REPUBLIC)

JINDŘICH HLADIL[1], FRANTIŠEK PATOČKA[1], VÁCLAV KACHLÍK[2], ROSTISLAV MELICHAR[3] and MARTIN HUBAČÍK [3]

[1]Institute of Geology, Academy of Sciences of the CR, Rozvojová 135, 165 02 Praha 6, Czech Republic; hladil@gli.cas.cz
[2]Department of Geology, Faculty of Science, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic
[3]Department of Geology, Faculty of Sciences, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic

(Manuscript received August 28, 2002; accepted in revised form March 11, 2003)

Abstract: The metamorphosed carbonate bodies structurally embedded in the East and South Krkonoše Complexes (ESKC — N Bohemian Massif, Krkonoše Mountains, Czech Republic) have principally two types of sedimentary precursors. The first precursor corresponds to Early Cambrian dolomitized oolites and microbialites (Dolní Albeřice) and provides practically the same fauna and geochemical features on residues as observed in Lusatia (Doberlug-Torgau Syncline). The Cadomian calc-alkaline meta-igneous rock sources, geochemically observed on this Early Cambrian, were also found in the Early Devonian of the Barrandian. The second precursor consists of open-sea calcitic wackestones/packstones and dolomitized packstones/grainstones (Poniklá and Horní Lánov, part) and yields fossil remnants, which are widely comparable with N Gondwanan carbonate sediments of the Bohemian type. The Middle-Late Devonian sedimentary continuation in the ESKC was likely absent (or restricted), and this was preceded by increased geochemical variation of insoluble residues in the marble precursors. Successively diversified compositions of trapped weathering products (regional to inter-regional background sediment, close to Post-Archean Average Australian Sedimentary distribution in REE, with a significant proportion of atmospheric depositions) suggest, that area precursors of the ESKC, Lusatia, Barrandian and Polish Central Sudetes were well separated and expanded to a great extent. The residues from carbonate rocks of the Sudetes correspond to a complex paleotectonic evolution — from Cambrian intracontinental rifting to Devonian arcs. However, there is a trend toward the East and with time toward the Middle Devonian, that Sudetic carbonatic residues indicate a variety of sources posing a wide spectrum of tectonic setting types.

Key words: Early Paleozoic, Gondwana, Bohemian Massif, Sudetes, recrystallization, rare earth elements, archaeocyaths, trilobites, dacryoconarids, oolites, microbialites.

Introduction

Metamorphosed Neoproterozoic-Paleozoic sediments, plutonites and volcanites in the southern and eastern parts of the Krkonoše Mountains constitute parts of the Krkonoše-Jizera Unit (Kachlík & Patočka 1998b; formerly the Krkonoše Metamorphic Complex, Chaloupský 1958). Narębski (1994) defined it as a part of the West Sudetic Terrane Assemblage. In the following text, it is accordingly referred to the Krkonoše-Jizera Terrane (KJT — Kachlík & Patočka 2001). The definition of this terrane is still rudimentary. It is difficult to state whether the KJT is a suspected microterrane or composed structure that originated on the contact between the Saxothuringian and Central Sudetic Terranes (Cymerman et al. 1997). Most generally, it is also considered to be an eastern projection of the Saxothuringian Terrane (Franke 2000). Three characteristics of the KJT are significant: (1) The initial Cambrian-Ordovician granitoid magmatism and protracted Early Paleozoic rift-related bimodal volcanism (Furnes et al. 1994; Patočka & Smulikowski 2000; Dostal et al. 2001), (2) the Late Devonian-Early Carboniferous subduction and HP-LT metamorphism followed by rapid uplift with equilibration of the HP-LT rocks in greenschist-facies conditions (Maluski & Patočka 1997; Collins et al. 2000; Marheine et al. in print) and, (3) the base of flysch sedimentation stratigraphically onlapping toward the West (Hladil et al. 1999; Kachlík & Patočka 2001). The complicated architecture of the West Sudetes with uncertain positions of repeatedly dismembered and amalgamated sutures offers a number of open questions about the dating of tectonometamorphic events (Bederke 1924; Franke et al. 1993; Oliver et al. 1993; Aleksandrowski et al. 1997; Żelaźniewicz 1997; Crowley et al. 2001; Winchester et al. in print). The reason is in successive assembling of East Avalonian and Armorican crustal chips and structural reorganization by movements on the TESZ-parallel (Trans-European Suture Zone) faults (Cymerman et al. 1997; Mazur & Kryza 1999; Pharaoh 1999; Winchester et al. in print).

Kachlík & Patočka (2001) characterized the KJT as a Variscan NW-directed orogenic wedge. Its lower part (autochthonous unit) is composed of the Cadomian granitoids (~540–587 Ma, Kröner et al. 1994) with their end-Proterozoic country rocks (Chaloupský et al. 1989; Gehmlich et al. 1997) that are unconformably overlain with Paleozoic rocks. This autochthonous part is exposed in the westernmost part of the KJT (at the Lusatian Terrane) and in the Ještěd Mountain Range, close to the South (Fig. 1). The very complex allochthonous parts are exposed mostly in the Krkonoše Mountains, farther to the E in the KJT (Kachlík & Patočka 1998b;

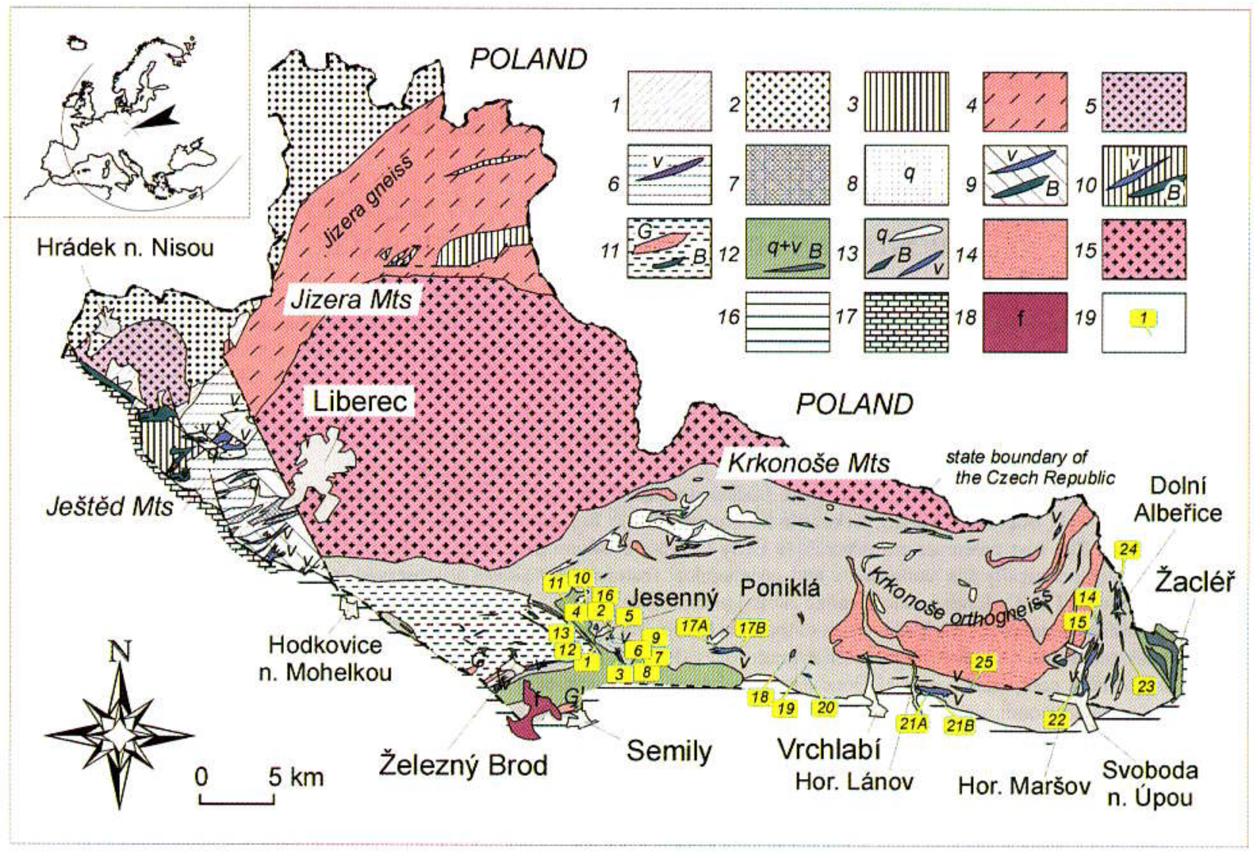


Fig. 1. A simplified geological map of the Krkonoše-Jizera Crystalline Unit (NE Bohemia, Czech Republic) with sampled sites in the South and East Krkonoše Complexes (numbered labels). Based on the previous map views (Kachlík & Kozdroj 2001; Kozdroj et al. 2001; position of sites by M. Hubačík). *Autochthonous to para-autochthonous units* (Neoproterozoic basement with Paleozoic cover): **1** — Late Proterozoic Machnín Group (metagraywackes, metapelites); **2** — Cadomian Zawidow Granodiorite; **3** — micaschists to gneisses in the Jizera Orthogneiss; **4** — Jizera Orthogneiss (~510–480 Ma); **5** — Rumburk Granite (510 Ma); **6** — Lower Paleozoic phyllites, graphite phyllites (with metabasite, quartzite and marble intercalations — Silurian "Ockerkalk" facies and Silurian-Devonian(?) microfossils in non-carbonate metasediments; **7** — Lower Paleozoic (Ordovician?) phyllites with quartzite intercalations thrust over Late Devonian sequence; **8** — quartzites; **9** — phyllites with intercalations of Middle to Upper Devonian marbles (evidence for the uppermost part of Givetian); **10** — Upper Devonian to Lower Carboniferous flysch deposits with intercalations of metabasalts, acid volcanics and marbles with fauna indicating the proximity of the Devonian-Carboniferous boundary. *Allochthonous units*: **11** — Cambrian-Ordovician volcano-sedimentary unit (metatuffites, roofing phyllites with Ordovician? ichnofauna, sills and dykes of metadiabase, rare metagabbros and picrites, and also phyllonitized granites); **12** — Železný Brod Volcanic Complex (metabasaltic pillow lavas, metatuffs and acid metavolcanics in the upper part with intercalations of marbles and mixed volcanogenic quartzites); **13** — sericite phyllites with intercalations of marbles and quartzites, basic volcanic products (volcanism waning towards top of the sequence); **14** — phyllonitized granites and orthogneisses. *Upper Variscan granites*: **15** — Krkonoše-Jizera Granite (310 Ma). *Platform sediments*: **16** — Permian-Carboniferous deposits of the Krkonoše Piedmont Basin; **17** — deposits of the Bohemian Cretaceous Basin. *Neovolcanics*: **18** — Tertiary volcanic rocks, namely basanites and olivine basalts (Pliocene). *Sampled sections:* Field-work places marked with numbered yellow labels (compare the list in appendix of the paper).

Kachlík & Kozdroj 2001; Kachlík et al. 2002). In these areas, the tectonometamorphic successions of Paleozoic rocks form a large antiform. The largely outcropped eastern and southern flanks of the antiform are represented by the East and South Krkonoše Complexes (ESKC — Chlupáč 1993; Kachlík & Patočka 1998a; Patočka et al. 2000; Dostal et al. 2001). The tectonically interlayered bodies of Cambro-Ordovician (and also younger?) porphyritic metagranites occur in inner parts of the flanks (Kachlík et al. 1999; Crowley et al. 2001).

Two ESKC subunits were defined, both with typically varying rock composition and metamorphic grade (Kachlík & Patočka 1998a). The lower unit consists of sericite-chlorite phyllites, roofing phyllites and two metavolcanic suites. The upper unit is made up of mainly sericite and graphite phyllites with quartzite and marble intercalations (volcanic products are subordinate). The radiometric datings of the ESKC rocks range from the Cambrian to Devonian (Oliver et al. 1993; Bendl & Patočka 1995; Maluski & Patočka 1997; Timmermann et al. 1999; Marheine et al. 2000 in print), whereas the paleontological indicators of age concerns mostly possible Ordovician and Silurian (Horný 1964; Chlupáč 1993, 1997). The uppermost allochthonous slices are typically marked with occurrences of blueschist metamorphism. The blueschist end-datum ~360 Ma is the latest Famennian, close to the Devonian-Carboniferous boundary (Maluski & Patočka 1997). The widespread greenschist facies overpress (~345–340 Ma) changed into shearing/thrusting that was expressed with NW-SE linear fabrics (~320–340 Ma; Marheine et al. in print) and terminated by intrusion of the Krkonoše-Jizera pluton (~328–313 Ma; Pin et al. 1987; Marheine et al. in print).

Assessment of previous data

The solid biostratigraphic dating concerns only the Ještěd para-autochthon, where metacarbonates associated with bimodal volcanics provided Devonian faunas (Koliha 1929; Chlupáč & Hladil 1992; Chlupáč 1993; Kachlík et al. 2002). Marbles occurring in structurally higher (allochthonous) parts of the KJT unit have not been directly dated yet, because the primary structures were intensely obliterated during the tectonometamorphic development. The absence of biostratigraphic and physical stratigraphic data is in contrast with abundance of the ESKC metacarbonates as well as their highly variable mineral composition, major element geochemistry, rock-fabric and variability of alteration effects (Svoboda 1955). Practically, only one record in the literature about the ESKC carbonates concerns finding of a real fossil (*Silesicaris nasuta* Gürich 1929; Silurian phyllocarid; Chlupáč 1997: p. 75).

The main importance was originally seen in collateral data from neighbouring slates. The classical locality is the Jizera River bed in Poniklá village. The fauna from concretions present in micaceous black slates was first collected by Perner (1919), who reported the "*Didymograptus*" sp. (= "*Climacograptus*" of Ordovician? age; Chlupáč 1953: p. 213). Reinvestigation by Horný (1964) provided graptolite branches of *Pristiograptus dubius* (Suess), *Monograptus priodon* (Bronn) and *Monograptus flexuosus*? Tullberg or *Mediograptus kolihai*? Bouček. The original assignment of this fauna to the Wenlockian must now be extended to Llandoverian-Wenlockian (consulting by P. Štorch). The pyritized stripes regarded as graptolites, inorganic metamorphic structures compared with the ichnotaxa, and other dubious fossil relics described by Prantl (1948) were problematic and the material does not exist any more. Other rejected possible graptolites were reported from the mid-south part of the ESKC (Chlupáč 1953 vs. 1998). The younger than mid-Silurian ages are based on microfossils (mazuelloids). Konzalová & Hrabal (1998) reported the Silurian-Devonian mazuelloids from Vysoké nad Jizerou, but assemblages described by Walter (2000), from Poniklá, correspond to the wide Ordovician-Devonian range. The same uncertain range provided the ichnofossil assemblages from neighbourhood of Železný Brod (Chlupáč 1997 — *Bifungites*, *Planolites*, *Spirophycus*, *Taphrhelmintopsis*, etc., and large star-shaped "*Teichichnus*" *stellatus*; originally deep water Ordovician, or Silurian? shales with relationships to flysch ichnofacies). However, a direct application of these "slate ages" to the marbles is in question since the slates and marbles may be separated by an unknown number of ductile fault zones.

It is remarkable that the ESKC does not show any indicators of the Middle or Upper Devonian sediments (Kachlík & Patočka 1998b). In contrast, the para-autochthonous Ještěd rocks yielded not only evidence for the Silurian-Devonian transitions (scyphocrinitids in "Ockerkalk" — Chlupáč 1993; or monograptids in "silica slates" — Watznauer 1934), but also clear late Givetian ages (Chlupáč & Hladil 1992), and further to the W also Frasnian (Galle & Chlupáč 1976) and Famennian (Koliha 1929; Zikmundová 1964 — the Cheiloceras-Wocklumeria zones). Possible Frasnian-Tournaisian sequences were also reported by Kachlík et al. (2002). On the N Krkonoše (Polish Karkonosze) slope, Skowronek & Steffahn (2000) reinvestigated the "Cambrian" Wojcieszów Limestone. They found advanced foraminifers with Silurian, Devonian (?) or even younger traits. Even the relatively distant Sudetic terranes usually have Middle and/or Late Devonian sediments, for example the findings in Kłodzko area (early Givetian — Hladil et al. 1999).

Several attempts have also been made to classify the ESKC marbles according to overall geological criteria (such as composition, shape, thickness and arrangement of bodies). The classification of carbonate stripes developed since 2½-stripe concept by Krutský (1968), through 3 stripes by Hoth (2000), including a thick "Cambrian" belt, to 4 stripes by Kachlík et al. (2002). The last concept of assembled stripes, with 4 structural levels is as follows: (1) Minor lenses and layers of dark grey coloured (graphite) marbles occur in transitional levels between the lower and upper part of the ESKC; any accumulations >5 m are very rare, the calcite >> dolomite; associated with sericite phyllites. (2) The ~100–200 m bodies of whitish-grey poorly foliated dolomitic marbles (the Jesenný or Lánov types) are typically embedded in the higher ESKC parts. Dark sericite-graphite phyllites or sericite phyllites prevail in some places. (3) The calc-silicate rock- and quartzite-associated grey to blue-grey coloured marbles form several bodies NW of Jánské Lázně and further to the Krkonoše high ranges. (4) Thick bodies of variegated dolostones represent a unique type of the ESKC marbles with white to ochre-umber-hued oolites intercalated within the former. Close spatial relations to acid volcanics, mostly porphyroids, were observed near Dolní Albeřice, where the Rb-Sr dating (~505 Ma — Bendl & Patočka 1995) indicates Middle Cambrian volcanism (compare the Cambrian ages in Encarnación et al. 1999). With very rough speculation only, the possible precursors of graphite marbles have been seen in the Wenlockian-Ludlowian facies, whereas the thickest and light-grey-coloured types occur in the Přídolian-Pragian (Emsian?) facies, both on examples from the Barrandian or Saxothuringian regions (Svoboda 1955; Chlupáč 1997). Rocks with relicts of oolites and early diagenetic dolomites indicate precursors of shallow-water Cambrian facies.

Concepts, methods and techniques

Several phases of metamorphism in the ESKC (Kachlík & Patočka 1998b; Marheine et al. 2000; Marheine et al. in print) correspond to strong effects upon preservation of the original fabrics and compositions of carbonate rocks. Because of these strong but selective alterations, only a few of the carbonate samples could reasonably be analysed as sediments. The investigation of overprinting had to find constraints for which these samples are still usable. Stage of metamorphic overprinting was assessed mainly according to relict-structure successions (thin-section optical and cathodoluminescence (CL) microscopy techniques), because the structured "ghosts" consist of bands of inclusions and lattice defects, which copy the past shapes of crystal aggregates. They constitute a discrete "memory" of the carbonate rock. Using a simple rule that young structures usually cut (or mask) the old, up to 3 or 4 recrystallization stages have been ordered within a single rock specimen. The lateral comparisons of these "short successions" (using the overlaps among differently timed successions) resulted in hypothesis about the ideal recrystallization path. Such an elimination of strongly metamorphosed rocks was the basic step.

An extensive investigation on fossil relics was based on 20 m^2 of slabs (using a quarry cutter), 120 thin sections (½ are polished sections) and 60 insoluble residues (in 5% acetic acid and formic acid, alternatively). Another set of 40 thin-sections (¼ polished) is related to the Dolní Albeřice dolostones. The composition of thin-sectioned or extracted fossils has been characterized using the X-ray diffraction (XRD), energy dispersive X-ray microanalysis (EDX) and electron microprobe analysis (EMP). This mineralogical and structural material inspection was very important, because an alteration grade of extracted "fossils" must be in agreement with the stage of overprinting (elimination of contaminants, artifacts, etc.). As concerns the preparation of insoluble residues for geochemistry, 5% formic acid was used for three weeks (carbonates from the ESKC, Lusatia, Polish Central Sudetes and Barrandian). The residues were analysed using the X-ray fluorescence (XRF) and instrumental neutron activation analysis (INAA) methods for selected trace elements and the REE. Specific effects of mineral carriers and element fractionation (e.g. phosphate), or "dilution" (e.g. quartz or relic carbonate) were checked using a combination of the EDX and XRD methods. The dissolution was always "imperfect", because the strong dissolution might cause a serious geochemical damage on minute aggregates and subcrystalline flocs. The data about non-carbonate components serve as proxies to tectonic settings of eroded rocks, as well as climates or large-regional to global features.

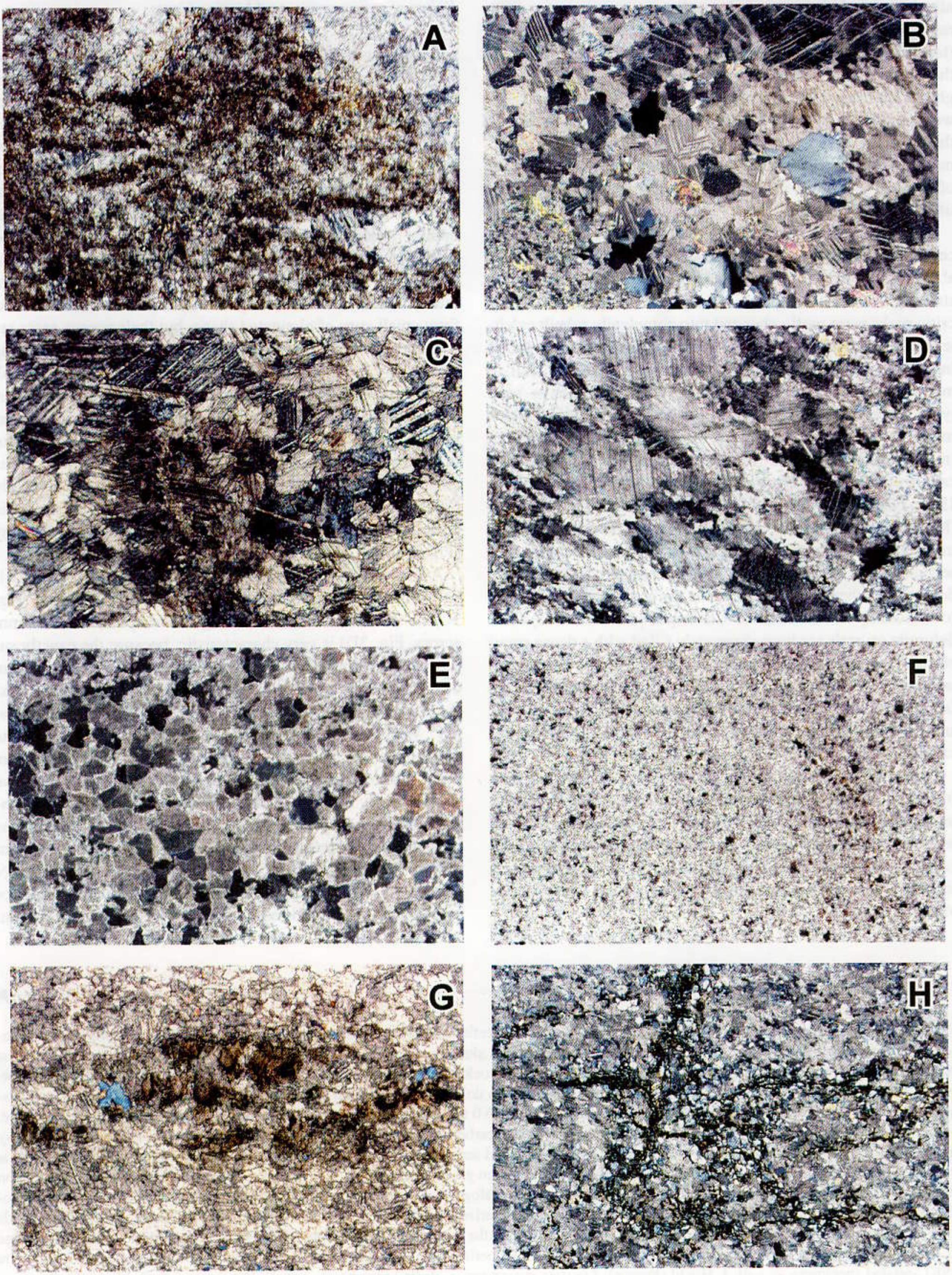
Results

Succession of metamorphic recrystallization stages and selection of the best preserved rocks

The youngest fabrics cut all other ghost fabrics and are post-metamorphic. Sub-rectangular networks of cracks with dissolution can exemplify these fabrics in the ESKC carbonates and another typical feature is the occurrence of rims with small carbonate crystals (Fig. 2H). It corresponds to brittle deformation and recrystallization in a relatively cold part of the deep phreatic zone. The calcite fossils and cements in the Dolní Albeřice dolostones were replaced by optically clear, young calcite crystal aggregates (bright yellow in CL). These small calcite cavities developed after the retrograde degradation of crystal size (including the origin of tectomicrites/mylonites). An epigenetic silicification on Dolní Albeřice dolostones developed in rims of quartz-carbonate hydrothermal veins. The timing of this process is between post-metamorphic alterations and intense shearing. The evident retrograde changes were observed on 80 % of samples (e.g. Fig. 2F). The early retrograde disruptions of the peak P-T crystal fabrics are expressed on calcites by healing of originally strong lamellae, as well as by the origin of new twin lamellae and gliding along microfractures. Rimming (satellite) calcite crystals of small size are typically early retrograde feature (e.g. Fig. 2D).

Although ~80 % of the ESKC marbles was changed in metamorphic retrograde conditions, the boudinaged marbles also provide undamaged relicts of the prograde fabrics. These prograde structures are very inhomogeneous (Fig. 2B). However, many of the large and elongated calcite crystals are relicts, not the growing porphyroblasts (corroded or recrystallized peripheries; typically dull in CL). The large calcite crystals that have sharp, dense and complex-banded twin lamellae correspond to peak metamorphic stages. The mosaics of mid-size but growing crystals pertain to diagenetic/early-metamorphic stages. Crystals in these mosaics "cannibalize" both the

Fig. 2. Diversified structures of metamorphic limestones and dolomites. Sites (localities) see Fig. 1 and Appendix in the text. **A** — Progressively recrystallized carbonate rock where calcite prevails over relics of diagenetic dolomite. Twinned lamellae and sliding defects are slightly developed. Relics of dolomite are brown-coloured due to the presence of iron-oxidic mixtures. These brown-coloured ghost structures are considered a possible archaeocyath bioclast; note the central opening and radial structures (major part of this image). Possible oolite ghosts border this structure (left). ESKC Site 10; polished section No. 862; W of Jesenný (Kamenice, Za Papírnou — lower part of hill slope). **B** — Coarse, basically progressively recrystallized carbonate rock. Large calcite crystals display strong lamellae, where subordinate dolomite interleaves calcite; sliding dislocations are superimposed on this structure. Degradation of crystal size is located in nests and irregular zones; it corresponds to metamorphic retrogression. Quartz is corroded. Site 4; polished section No. 868; W of Jesenný (U Staré Vody). **C** — Large-size neomorphic calcite crystals replaced a dolomite precursor. Prevailing thin lamellae are densely spaced. Polished section No. 856; Horní Maršov (Water Tank). **D** — Crystal-size reduction on margins of neomorphic calcite crystals — retrogressive origin of small crystals in collar-shaped structures mantling larger crystalline relics. Site 5; polished section No. 867; NNE of Bozkov (Brook Junction). **E** — A specific metamorphic dolomite characterized by numerous spot-shaped crystal defects with absence of visible zonal growth. Contacts of crystals are linear, with calcite interstitial fills (white lines). Site 21B; polished section No. 864; Horní Lánov (base of the Active Quarry). **F** — Mylonitic dolomite rock with dispersed small calcite crystals of young generation. Site 15; polished section No. 868; Maršov (2.2 km S of the Horní Maršov Cave). **G** — Relics of old (early diagenetic) dolomite rim; the inherited stylolite locations are preserved from pre-metamorphic times. Site 10; polished section No. 863; W of Jesenný (Kamenice, Za Papírnou — upper part of hill slope). **H** — The effect of young brittle deformation is expressed as a cube-shaped system of dislocations, accompanied by grinding and dissolution of carbonate and formation of a new generation of small crystals of quartz and dolomite. Site 13; polished section No. 853; NW of Bozkov (Pod Domání). White polarized transmitted light, crossed nicols, horizontal edge of each photograph 5.5 mm.


A
B
C
D
E
F
G
H

allochems and cements of the sedimentary precursor. With rapid recrystallization, the centrifugal movement of inclusions (toward interstitial spaces) caused bluring (or damaging) of the original rock fabric (e.g. Fig. 2A, marble with Fe-oxidic ghosts after fossils; or G, where medium-sized crystal mosaics were consumed by large calcite specimens). It is characteristic that many prograde crystal mosaics observed in the ESKC marbles were imperfectly "purified" (blurred with a number of mineral and fluid inclusions, including carbonate crystallites — Fig. 2C).

Two processes differ from simple prograde-retrograde successions. The first involved the massive fabrics of low-permeable dolomites from Dolní Albeřice, which survived until the strong greenschist overpress, when the boudinaged oolitic/micritic rocks were partly changed into completely rebuilt calcitic marbles subjected to highly ductile deformation (CL-imaging shows nebular bands of alternating, moderately dull to moderately bright calcite streaks). These contrastive rock types closely abut to thin envelopes of boudins, where maximum shear movements were localized on slip surfaces (minute banding of carbonate cataclasites and silicates). The calcitization above must be a fluid-induced process (Erickson 1994; Fisler & Cygan 1999) rather than a solid-state change (Matthews et al. 1999), particularly if we consider the extremely rapid growth of low-magnesium calcite mass. The second highly different rock types represent "coarse-mosaic" dolomites, where interstitial seams among crystals are sharp (occasionally with thread of CL-bright yellow calcite). The dolomite crystals are homogeneously filled with a dense spray of tiny inclusions (not zoned, not lamelled, no centrifugal movement of inclusions, and dull in CL). To obtain such a fabric, very slow crystallization is demanded for a long time and with only a little chemical difference from the hypothetical precursor.

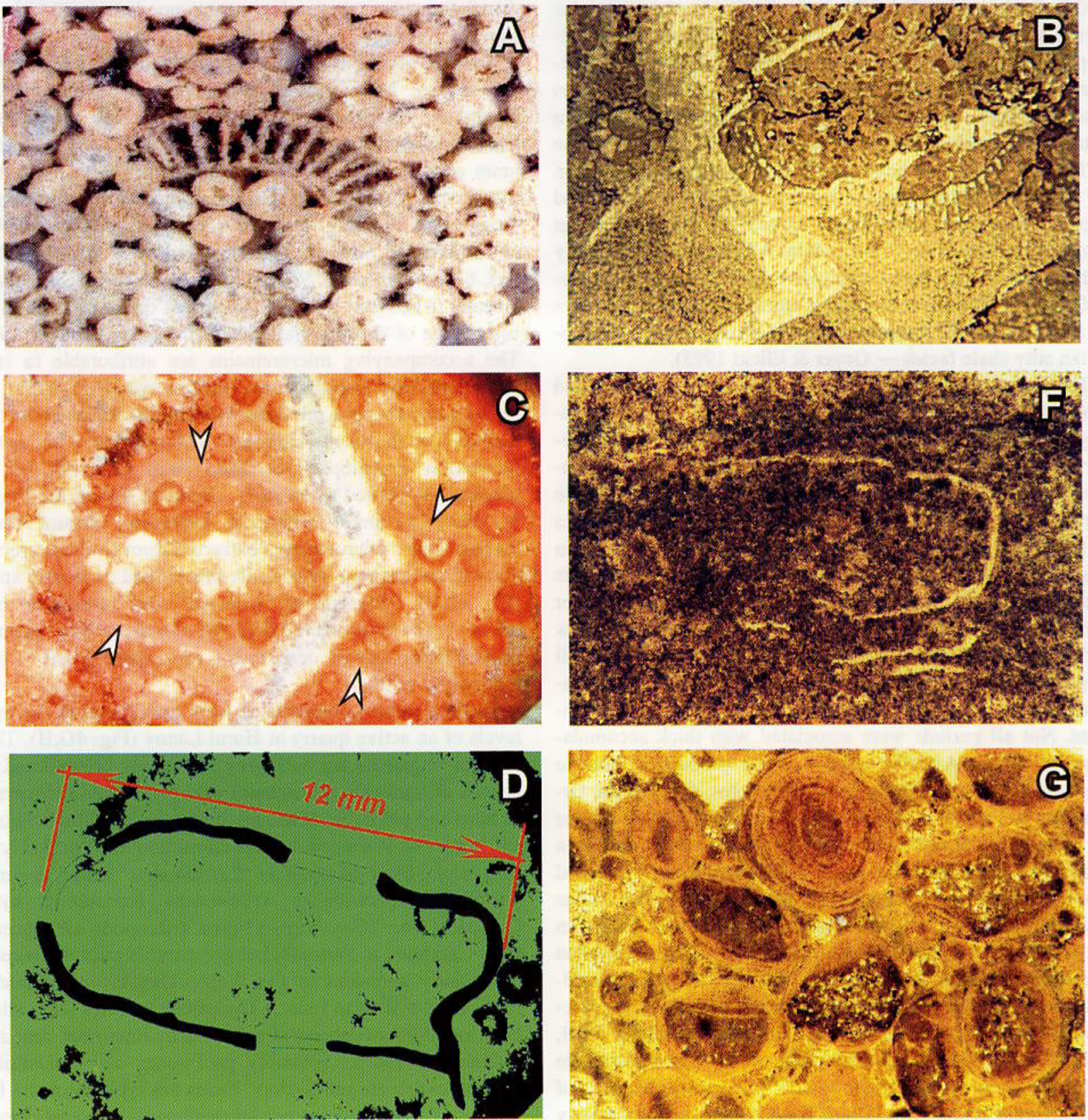
Owing to the results of this analysis, the reliable material (relevant to paleontological and geochemical features of rock precursors) was practically reduced only to calcite marbles with visible diagenetic/early-metamorphic prograde crystallization stages or, alternatively, to these "blocked" dolostones sheltered from transformation to "neoplasmic" calcite marbles.

Relics of sedimentary and biotic objects

An archaeocyath fragment, which was found during a joint field trip by Ch. Pin in the Dolní Albeřice quarry (the specimen is housed in the Inst. Geol. AS CR; coll. J. Hladil), is in the best state of preservation from all of the sectioned fossil material. Comparative morphology studies made on the Lusatian material and Lower Cambrian of the world (TU Freiberg Collections) clearly confirmed the determination of this fossil as an archaeocyath, which is similar to *Erismacoscinus* Debrenne (possible *E. tainius* Elicki & Debrenne in comparison with thin-sectioned material from Lusatia and also photographs and descriptions by Elicki & Debrenne 1993). Commonly associated archaeocyaths *Afiacyathus* Voronin also form small cups of elongated shape, but their porous septa are interconnected with synapticulae and an inner wall containing numerous canals. It is not so compact as the simply pored wall of *Erismacoscinus*. The stratigraphic range of the genus *Erismacoscinus* Debrenne 1958 is Tommotian–Botoman. An expertreport by F. Debrenne from the Museum of Natural History in Paris was fundamental for the confirmation of the archaeocyathan nature of this fossil (Fig. 3A) and its Early Cambrian age. Another candidate to be recognized as a relic of an archaeocyath was found in a thin section W of Jesenný (Fig. 2A).

A small skeletal fossil found by V. Kachlík in the Dolní Albeřice quarry has well-preserved trilobite microstructure (Fig. 3C,E). The oval to sub-rectangular shape (about 12 mm across, Fig. 3D) is very characteristic, because the exactly superposable trilobite sections are common in Lower Cambrian of Lusatia (TU Freiberg collections). Both correspond to box-shaped trilobite glabellae. They can be compared with "*Bonnia*" Walcott (2 or 3 genera?, presently revised by trilobite specialists). In "*Bonnia*", the anterior ends of glabellae are blunt, anterolateral corners expanded and glabellar furrows are extremely shallow (Palmer 1964). Small but sturdy "*Bonnia*"-trilobites seem to be typical inhabitants of carbonate seas (in Bonnia-Olennelus Biozone), being widely reported from different facies of North America (California, Colorado, N Greenland — Blaker & Peel 1997), but also Central Asia or other places (e.g. Kazkhstan — L.B. McCollum pers. comm.

Fig. 3. Relics of the Lower Cambrian fossils and ooids in polished sections and their comparison with unmetamorphosed rocks from the Doberlug-Torgau area of Lusatia. **A** — A fragment of an archaeocyath skeleton, possible *Erismacoscinus* in oolite. The ooids and the bioclast are dolomitized. Very young transparent calcite crystals replace the rock matrix and cement. Quarry at Dolní Albeřice. Polished section, horizontal edge 6.8 mm. **B** — Analogous fragments of archaeocyaths in dolomitized microbial packstone with microbial structures of *Renalcis*-type. Doberlug-Torgau P8/1706, 98. Thin section, horizontal edge 16.0 mm. **C** — A section across a small box-shaped cephalon of trilobite, possible *Bonnia*, in dolomitized ooidal carbonate rock. The quartz-carbonate veinlets are white; the trilobite skeleton is pink with a glassy appearance (marked with arrows). Quarry at Dolní Albeřice. Polished section, horizontal edge 15.3 mm. **D** — The same object; the "shell" is traced using the image analysis techniques (artificial colours, black on green background). **E** — The same object; microstructure of skeleton (blue light from lower and oblique upper illuminations). **F** — An analogous section across a box-shaped cephalon. Strongly dolomitized ooidal packstone. Doberlug-Torgau P18(B)/1630, 88. Thin section, horizontal edge 12.0 mm. **G** — Relic structures after dolomitized ooids form dark grey coloured rings in neomorphic carbonate structure of the rock. Doberlug-Torgau P2/1614, 103. Thin section, horizontal edge 12.0 mm. **H** — Coated grains with quartz silt and large ooids. Doberlug-Torgau P2/1706, 95. Thin section, horizontal edge 5.5 mm. The ESKC-related specimens — coll. J. Hladil (Prague); Lusatian specimens — drilled rock cores, coll. B. Buschmann & O. Elicki (Freiberg).


A
B
C
F
D
12 mm
G

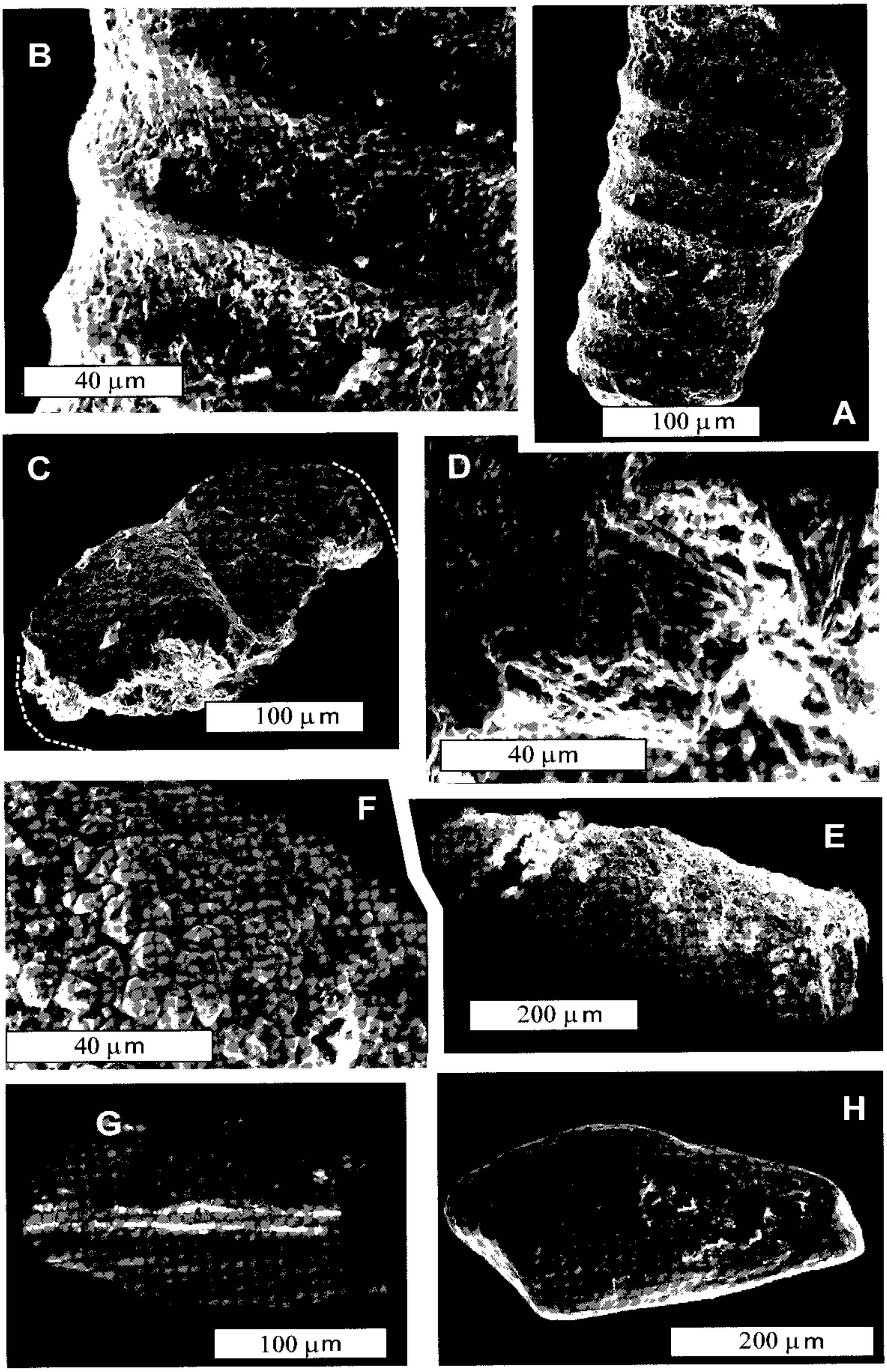
2002). Such sudden "island hopping" migrations of trilobites from Laurentian to Gondwanan carbonate shelves are generally possible (late Early Cambrian breakdown of provincial barriers — Geyer & Landing 2001). Other small trilobite chips resemble, with some uncertainty, the "*Kingaspis*" debris from Jordan (TU Freiberg collections; Elicki & Shinaq 2000). The "*Kingaspis*" trilobites have strictly domed dorsal exoskeleton (N African complete specimens); they were spiny and formed cephalic and pleural doublures. Although suggestions about "*Bonnia*" or "*Kingaspis*" from Dolní Albeřice have separately rather a speculative than a conclusive character, a general Early Cambrian trilobite indication is worth mentioning. The *Serrodiscus-Lusatiops faunulae* have not been indicated yet (Lusatian silty shale facies — Geyer & Elicki 1995).

The archaeocyathan and trilobite remnants were embedded mostly in oolites (Fig. 3A,C), rarely in micrites. The sedimentary fabrics have largely been based on exceptionally preserved boudins from the Dolní Albeřice quarry (the easternmost ESKC), but ghosts of relic oolites in prograde metamorphic fabrics (Fig. 2A) are also found at other places in the ESKC. The ooids are usually well-sorted, ¼ to 2 mm large; the maximum thickness of oolites goes over 30 m. As is generally known, the formation of oolites requires gentle or periodic wave actions in warm marine-waters which allow carbonate precipitation on all sides of a grain of sand or shell fragment. Favourable conditions are high aragonite saturations in seawater by low binding capability of benthic organisms. Not all periods were associated with thick accumulations of oolites. A really massive oolitic production dates to the Late Proterozoic-Early Cambrian stages, whereas the Ordovician to Devonian periods provided only a limited chance for expansions of oolitic facies. This simple fact is used as a supporting argument in favour of biostratigraphically deduced Early Cambrian ages. In addition, the Dolní Albeřice oolites and microbialites are nearly identical to the Lower Cambrian carbonates of Lusatia (Doberlug-Torgau Syncline, Zwethau Formation — Elicki 1999; Fig. 3F–H herein). The next worldwide expansion of oolitic facies occurred with the Early Carboniferous "aragonite-facilitating" episodes (Sandberg 1983, or Mistiaen 1984), but this alternative seems to be implausible in the question relating to the ESKC. The 90%-prevalence of early diagenetic dolomite, which formed even before the early dissolution of aragonite chips, corresponds to evaporitic marine environments.

The microfossil assemblage from calcitic marbles of Poniklá differs from the above mentioned summary. The maghemite-chlorite-siderite cast of a strictly conical shell bears rings and longitudinal ribs (Fig. 4A,B). This shape is more comparable with dacryoconarids than with the distinctive forms of small Early Cambrian molluscs (collections in Prague and Freiberg, respectively). The shell morphology corresponds to *Nowakia* Gürich, possibly *N. acuaria* (Richter), because all other *Nowakia* species have much larger diameters (>120 μm) by rather imperfect ornamentation in this early stage of dacryoconarid shell formation (Bouček 1964). The accompanying microremains are attributable to small planktonic brachiopods *Acrotreta* Kutorga (Fig. 4C,D). Fe-oxidic and carbonatic mixtures with chlorite replaced the original shell of phosphatic-carbonatic composition. Although the "*Acrotreta*"-brachiopods occurred from Cambrian to Holocene, they started to be really abundant during the Pragian (as related to the Armorican-E Avalonian Terrane Assemblages). Other microremains extracted from residues are very unclear, for example of possible brachiopod or crinoid spines (Fig. 4E,F). Although the "*Nowakia*" and "*Acrotreta*" casts are not perfectly preserved (Fig. 4A–D), they allow reasoning about Pragian age (*N. acuaria* is a zonal index fossil — biostratigraphic marker).

Specific fossil microremains were also found in the upper levels of an active quarry at Horní Lánov (Fig. 4G,H). These skeletal fragments are dark grey and honey-brown-hued and consist of francolite (phosphate) with perfoliated tiny crystals of mica and dolomite. These microremains are abraded blades and spines of V-shaped cross-sections and most probably belong to phyllocarids, possible "*Ceratiocaris*" Salter, or similar primitive malacostracan crustaceans (consulting by I. Chlupáč). The "*Ceratiocaris*"-type arthropods are traceable from Cambrian to Permian, but comparable microremains are particularly abundant in the Wenlockian-Přídolian interval (mid- to end-Silurian times). The calcite marbles (only slightly dolomitic) have ghosts after bioclastic lime-mud-supported sedimentary fabrics (possibly packstones and calcisiltites). Related carbonate ramp-slope facies are typical for the Late Silurian-Early Devonian oceanic sediments of warm climates

Fig. 4. Examples of the best preserved fossil relics from insoluble residues after dissolution of marbles. **A** and **B** — A maghemite-chlorite-siderite cast of a dacryoconarid shell, possible *Nowakia*. Note extremely narrow early part of the shell (d = 120 μm); longitudinal ribs are partly preserved. **C** and **D** — A maghemite-chlorite-siderite cast of *Acrotreta* valve (small planktonic brachiopod), size < 300 μm; a general view (C) and detail of coarse crystal aggregates in broken cast (D), which shows elongated crystal shapes of siderite > maghemite (with other Fe-oxides) and obliquely oriented platelets of chlorite (with traces of mica). Small amounts of chalcedony quartz are present (small bulbs). **E** and **F** — A pseudomorph of small rod-shaped bioclast consisting of pyrite-goethite-mica aggregates with phosphate and dolomite admixtures. **G** and **H** — Phosphatic bioclasts. The V-shaped rod (G) consists of francolite phosphatic mass with subordinate contents of dolomite and dispersed mica; parts of phyllocarid carapaces, possible *Ceratiocaris* (opinion of I. Chlupáč). Abraded blades of laminated phosphatic bioprecipitates are most likely also disarticulated parts of arthropods. The photographs A to F were taken on the material from the locality of Poniklá, Dolský potok; G and H from Horní Lánov, base of the Active Quarry. All in SEM, with the exception of G (light microscopy). The insoluble residues were obtained by the buffered formic acid dissolution process. Mineralogy was interpreted from the EDAX and XRD data. The ESKC-related specimens come from the collections of M. Hubačík (Brno and Semily).


B
40 µm
100 µm
A
C
100 µm
D
40 µm
F
40 µm
E
200 µm
G
100 µm
H
200 µm

(anywhere, from the Appalachians, through the Barrandian to S China, for instance).

Rare-earth and trace elements in insoluble residues of marbles and compared carbonate rocks

The chondrite-normalized REE distribution patterns of the insoluble residues from the ESKC metacarbonates show a distinct enrichment in light REE (LREE), small negative Eu anomaly, and rather unfractionated and almost flat distribution of heavy REE (HREE) (Fig. 5A). The ESKC metacarbonate residues are quite similar to Post-Archean Average Australian Sedimentary (PAAS) rock (Nance & Taylor 1976), as well as to the other typical post-Archean sediments (e.g. Taylor & McLennan 1985; McLennan & Taylor 1991; McLennan 2001) according to the lanthanide distribution patterns — nevertheless, compared to these standards, they are depleted in REE abundances by the factor of 5 to 10 due to the generally low lanthanide concentrations in carbonates (Bowen 1979) which survived in finely crystalline mineral mixtures of the residues. Examples of the other carbonate insoluble residues of the Bohemian Massif — from the Barrandian (Early Devonian), Lusatia (Early Cambrian) and Polish Central Sudetes (problematic Cambrian, Middle Devonian, and Late Devonian) generally display the same features of chondrite-normalized REE distribution patterns (Fig. 5B–D). However, the depletion in lanthanide concentrations similar to that of the ESKC marble insoluble residues was revealed only in some samples from the Polish Central Sudetes (Middle Devonian, Mały Bożków locality) (Fig. 5D); the only REE-depleted and Ca-rich sample from the Koněprusy reef (Early Devonian, the Barrandian) seems to be an exception, too (Fig. 5B, Table 1).

The data on REE concentrations in insoluble residues obtained from representative samples of carbonate rocks from the ESKC, Barrandian, Lusatia and Polish Central Sudetes were double-normalized by PAAS values (Nance & Taylor 1976) and by Lu_N (i.e., Lu values of every individual sample normalized by PAAS). The purpose was to minimize the effect of dilution of lanthanide concentrations in the rock residues by abundant undiluted carbonates and detrital-to-silicification quartz (Fig. 6). The double-normalized REE-distribution patterns of the residue samples of the ESKC Early Cambrian marbles (e.g. from Dolní Albeřice and Horní Lánov, part of which may be Silurian) as well as of the Lusatian Early Cambrian dolomites reflect slight deviations from the normalizing REE profile, which can be interpreted as an influx of calc-alkaline igneous-rock products from the surrounding region (not from atmospheric deposits — see Discussion). If simply compared with igneous rocks, it may suggest continental arc to active margin sources — CAAM (Bhatia 1985; Bhatia & Crook 1986; Girty et al. 1993; McLennan et al. 1993; and Fig. 6A,B herein). As mentioned by one of the reviewers, Ch. Pin, the mixing effect of local and global sources of the background sedimentation have not been completely understood yet and a simple inference to be made on geodynamic setting is may be difficult to ascertain.

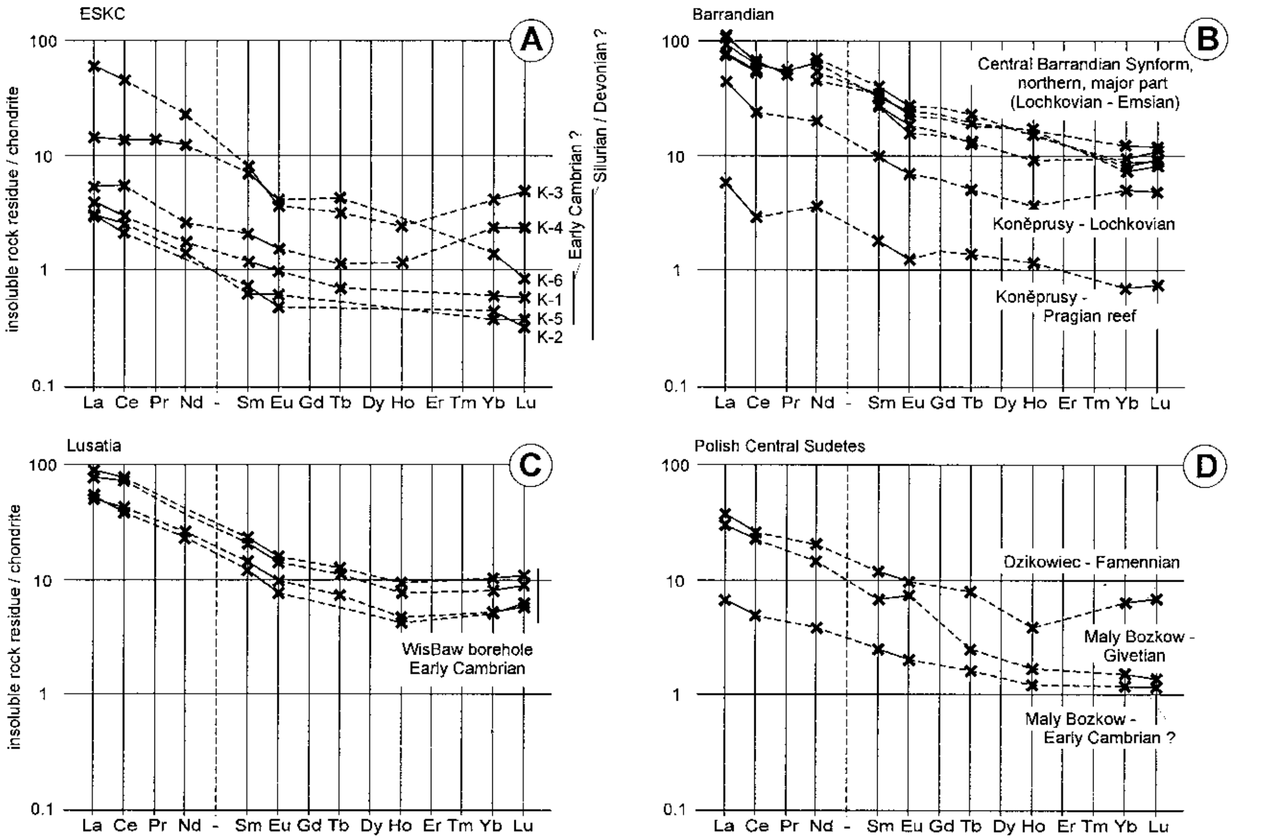


Fig. 5. Distribution patterns of REE concentrations in insoluble residues normalized by chondrite composition (Anders & Grevesse 1989). **A** — ESKC marbles (Cambrian and Silurian–Devonian); **B** — Barrandian (Early Devonian) limestones; **C** — Lusatian (Early Cambrian) dolomites; **D** — Polish Central Sudetes (Cambrian?, Middle Devonian, and Late Devonian) carbonate rocks.

Table 1: Abundances of rare earth elements and selected trace elements; selected macroelements and Th/U ratio — round mean values. Results of the INNA-XRF analyses of residues, i.e., the formerly dispersed weathering products trapped in carbonates were moderaltely (and up to various stage — cf. abundance of Ca) concentrated by means of three-weeks dissolution in 5% formic acid. *Abbreviations of sites*: **K** = Krkonoše-Jizera area: K-1 — Dolní Albeřice Quarry; K-2 — Poniklá, Dolský Brook, Middle, sample No. 2; K-3 — Poniklá, Dolský Brook, South, sample No. 3; K-4 — Poniklá, Poniklá Cave, sample No. 6; K-5 — Horní Lánov Active Quarry, Crusher, sample No. 9; K-6 — Horní Lánov Active Quarry, 2nd level, sample No. 12. **B** = Barrandian area: B-1 — Velká Chuchle Quarry, conodont point No. 7 of L. Slavík — Lochkovian; B-2 — Na Cikánce Quarry, conodont point No. 7 of L. Slavík — Lochkovian; B-3 — Koněprusy Quarry West, L. Slavík's conodont point 2 — Lochkovian; B-4 — Koněprusy Quarry West, conodont point No. 6 of L. Slavík — Pragian; B-5 — Mramorka Quarry, Chýnice/Zbuzany, bed interval No. 6 — Pragian; B-6 — Stydlé Vody Quarry, bed interval No. 7 — Pragian; B-7 — Mramorka Quarry Chýnice/Zbuzany, bed interval No. 13 — Zlíchovian. **L** = Lusatia-Doberlug Syncline: L-1 — northern flank of Doberlug Syncline WBW 1612, 277.5 m — Early Cambrian; L-2 — N Doberlug Syncline WBW 1612, 280.0 m — Early Cambrian; L-3 — N Doberlug Syncline WBW 1612, 389.0 m — Early Cambrian; L-4 — N Doberlug Syncline WBW 1612, 396.5 m — Early Cambrian. **S** = Polish Central Sudetes: S-1 — Dzikowiec, Playground Quarry — Famennian; S-2 — Mały Bożków, "Coral Quarry" — Givetian; S-3 — Mały Bożków, "Malaysia" Quarry — unknown Paleozoic age.

	Sr	Rb	Ba	Cs	Th	U	Ta	Nb	Zr	Hf	Th/U	Fe	Ca	Na	K	La	Ce	Pr	Nd	Sm	Eu	Tb	Ho	Yb	Lu	Y	Sc	Cr
	[ppm]										ratio	%				[ppm]												
K-1	161	3.2	18	0.2	0.3	0.1	-	3	22	0.2	2.4	0.2	30.4	-	0.1	1.8	3.3	-	1.5	0.3	0.1	-	0.1	0.1	-	4	0.4	2.1
K-2	-	6.8	38	0.3	-	0.6	-	8	44	0.3	0.4	0.2	22.1	-	0.2	1.3	2.4	-	-	0.2	-	-	0.1	0.1	-	2	0.4	4.8
K-3	-	86.6	179	2.4	7.4	0.7	0.5	7	177	4.7	9.9	1.7	1.8	0.1	4.9	27.1	51.7	-	18.8	2.1	0.3	0.2	0.2	1.0	0.2	8	3.0	39.3
K-4	-	46.2	152	2.2	2.9	2.5	0.5	7	99	2.7	1.2	0.5	15.3	-	2.0	2.4	6.1	-	2.1	0.5	0.1	0.1	0.1	0.6	0.1	11	2.8	34.1
K-5	137	6.9	92	0.5	0.5	0.5	0.1	6	25	0.4	0.9	0.2	22.2	-	0.3	1.3	2.9	-	1.1	0.2	0.1	-	0.1	0.1	-	5	0.4	4.1
K-6	90	11.4	74	0.6	0.9	0.8	0.6	9	51	0.8	1.2	0.2	20.9	-	0.5	6.4	15.6	2.3	10.3	1.8	0.4	0.3	0.3	0.3	-	14	0.9	9.8
B-1	-	68.7	312	4.2	10.0	2.2	0.7	11	112	2.8	4.6	23.3	4.4	0.2	2.1	34.5	61.0	-	37.8	9.0	2.2	1.1	1.5	1.8	0.3	28	11.2	127.5
B-2	204	47.5	117	2.9	6.6	4.6	0.6	16	126	2.3	1.4	4.1	13.1	-	2.3	35.5	63.3	-	58.7	10.5	2.7	1.4	1.4	2.2	0.3	66	7.1	203.1
B-3	-	112.0	207	5.5	4.8	2.1	0.6	22	153	3.3	2.4	3.4	5.7	0.8	2.2	20.9	27.4	-	16.9	2.6	0.7	0.3	0.3	1.3	0.2	26	6.7	70.8
B-4	164	-	18	0.2	0.3	0.1	0.2	6	25	0.1	2.0	0.2	38.0	-	-	2.7	3.3	-	3.0	0.5	0.1	0.1	0.1	0.2	-	4	0.4	2.4
B-5	347	149.1	873	11.2	12.7	2.8	1.1	26	252	4.5	4.5	10.3	1.6	0.1	3.8	50.1	74.3	-	44.8	7.1	1.8	0.8	1.4	2.0	0.3	52	11.9	97.2
B-6	2,197	145.3	570	9.4	14.8	2.3	1.3	42	236	6.0	6.4	5.0	2.0	0.1	3.7	49.2	76.3	8.6	8.6	7.1	1.6	0.8	0.8	2.4	0.4	68	13.2	99.2
B-7	253	77.1	1,485	6.8	9.0	6.2	1.1	34	250	3.9	1.4	11.6	4.0	0.1	0.9	42.8	71.7	9.3	54.1	8.5	2.4	1.2	1.5	3.1	0.4	96	9.0	136.9
L-1	514	78.2	392	4.2	8.4	1.6	0.6	12	176	2.9	5.4	3.4	14.1	1.0	2.4	41.2	89.7	-	35.0	6.1	1.5	0.8	0.9	2.7	0.4	46	12.5	58.6
L-2	347	75.7	427	3.8	7.4	1.2	0.5	11	160	2.4	6.2	3.2	16.1	0.8	2.2	36.1	85.4	-	31.9	5.6	1.4	0.7	0.7	2.1	0.3	40	10.0	47.5
L-3	549	39.4	368	1.4	5.6	1.1	0.5	7	77	2.2	5.3	1.4	22.4	1.0	1.2	23.4	49.2	-	22.2	3.8	1.0	0.4	0.4	1.3	0.2	22	7.2	34.1
L-4	3,160	54.2	470	2.6	6.4	1.5	0.4	6	125	2.3	4.1	1.8	13.3	1.3	1.8	24.4	44.7	-	20.2	3.2	0.8	0.4	0.4	1.3	0.2	20	10.5	50.5
S-1	357	23.8	106	2.2	1.8	0.9	0.2	6	107	1.3	2.0	1.5	30.4	0.4	0.5	17.1	30.2	-	17.1	3.2	1.0	0.5	0.4	1.6	0.3	30	6.2	39.1
S-2	1,353	24.1	346	0.6	4.8	3.9	0.2	7	55	1.5	1.2	1.5	33.9	0.2	0.8	13.9	26.4	-	12.5	1.8	0.7	0.2	0.2	0.4	0.1	8	3.7	43.3
S-3	195	7.4	26	0.3	0.3	0.1	0.1	11	25	0.3	2.5	0.6	36.0	-	0.3	3.1	5.7	-	3.3	0.7	0.2	0.1	0.1	0.3	-	13	2.1	7.9

However, the patterns similar to above Cambrian patterns are still traceable on Lower Devonian samples from Barrandian, and a slightly similar pattern can also be seen on a single specimen from the Polish Central Sudetes (Mały Bożków locality — Middle Devonian) — however, in the latter area, source rocks with conspicuously fractionated LREE/HREE were substantially involved (Fig. 6D). In the ESKC Silurian-Devonian (e.g. Poniklá area), these "continental" features also occur but to a lesser extent. The majority of the ESKC and Sudetes samples, with an exception for the Cambrian, reveal either oceanic island-arc or passive continental margin influences.

Slight arch-shaped deviations seen in several normalized REE diagrams are caused by the presence of organogenic/diagenetic phosphate. This bias is demonstrated by Barrandian samples (chips of conodont-teeth elements) and partly also with the ESKC samples (Silurian? "*Ceratiocaris*"-microremains; Horní Lánov, part of which may be Cambrian).

The diagram of Hf/Yb vs. La/Th (employing representative elements of REE, HFSE — high-field strength elements, and the least mobile LILE — large ion lithophile elements) can be alternatively used for evaluation of the predominance of either mafic or felsic rocks in clastic sediment source — an approximate boundary between mafic and felsic sources was constructed on the basis of data following authors such as Floyd (1989), Floyd et al. (1991) and Wilson (1993). The Hf/Yb vs. La/Th discrimination on the ESKC and Polish Central Sudetes metacarbonatic residues are conspicuously scattered, compared to the closely spaced data for the Barrandian and Lusatian samples (Fig. 7). A considerable diversity of source rocks can therefore be presumed for the former groups of rocks.

An analogous difference between the ESKC-Polish Central Sudetes and Barrandian-Lusatian assemblages is visualized using the Hf/Sc vs. La/Th plot (Fig. 8). Although these characteristics for sediments have bias from incompletely known fractionation pathways (e.g. concentration of Sc in lateritic crusts — Ni, Co, Al affinites), it provides, according to first experiences, an interesting discrimination capability that is related to mafic-felsic depletion of Sc in igneous source rocks. The Barrandian-Lusatian assemblage displays the data scatter, which is strongly focused to CAAM field. Application of these proxies to the Polish Central Sudetes indicates the influence of oceanic igneous sources (from oceanic island-arc to oceanic within-plate environments).

Altogether, these ratios — Hf/Yb, Hf/Sc and La/Th — combined and plotted for the ESKC specimens show large variability (usually with little shifts toward passive continental margin compositions). The possible PCM influences (compare: Taylor & McLennan 1985; Floyd et al. 1991; McLennan et al. 1993) are best exemplified by a sequestered point, which stands for one of the Silurian-Devonian samples from the Poniklá area (Fig. 8, upper right).

The Th/U ratio based on insoluble residues from marbles strongly fluctuates (0.4 and 9.9; Table 1). Expected metamorphic mobility of uranium complexes practically precludes any

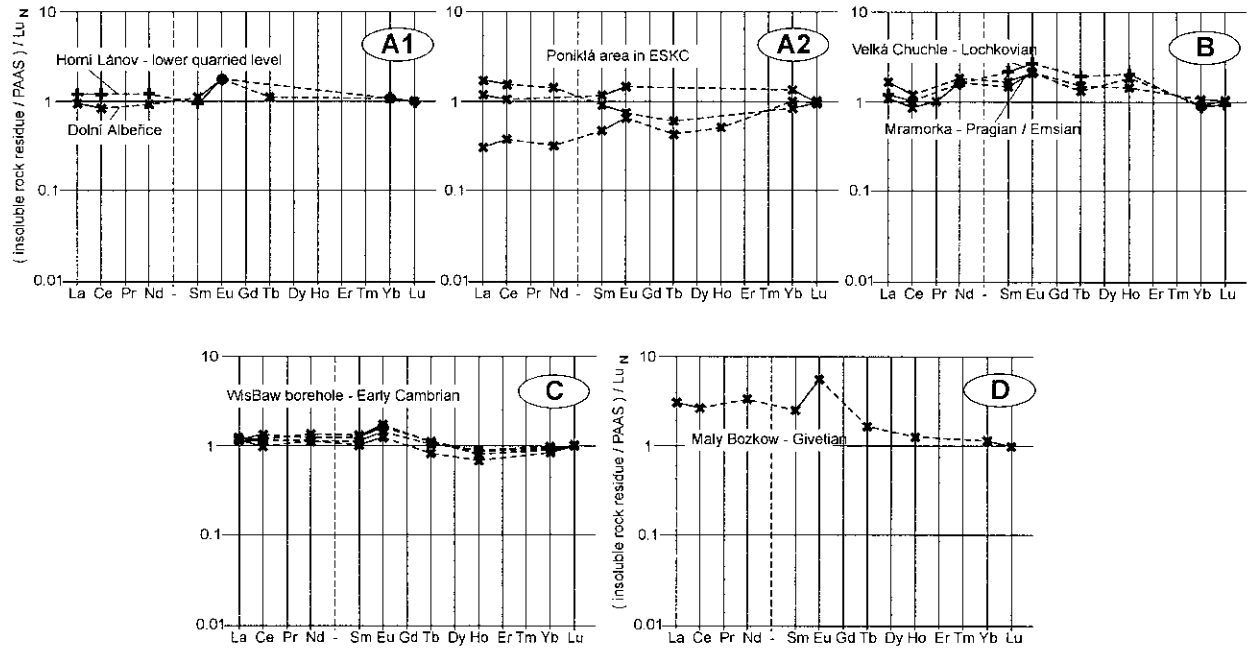


Fig. 6. Distribution patterns of REE concentrations in the insoluble residues double-normalized by Post-Archean Average Australian Sedimentary (PAAS) rock values (Nance & Taylor 1976) and by Lu_N (i.e., Lu values already normalized by PAAS) to minimize the effect of dilution of lanthanide concentrations by carbonates and quartz. **A1** — ESKC Early Cambrian marbles (from Dolní Albeřice and Horní Lánov); **A2** — ESKC marbles of suspected Late Silurian to Early Devonian age (Poniklá area); **B** — Barrandian (Early Devonian) limestones from Velká Chuchle and Mramorka; **C** — Lusatian unmetamorphosed Early Cambrian dolomites (WisBaw borehole); **D** — Middle Devonian limestone sample from the Polish Central Sudetes (Mały Bożków area).

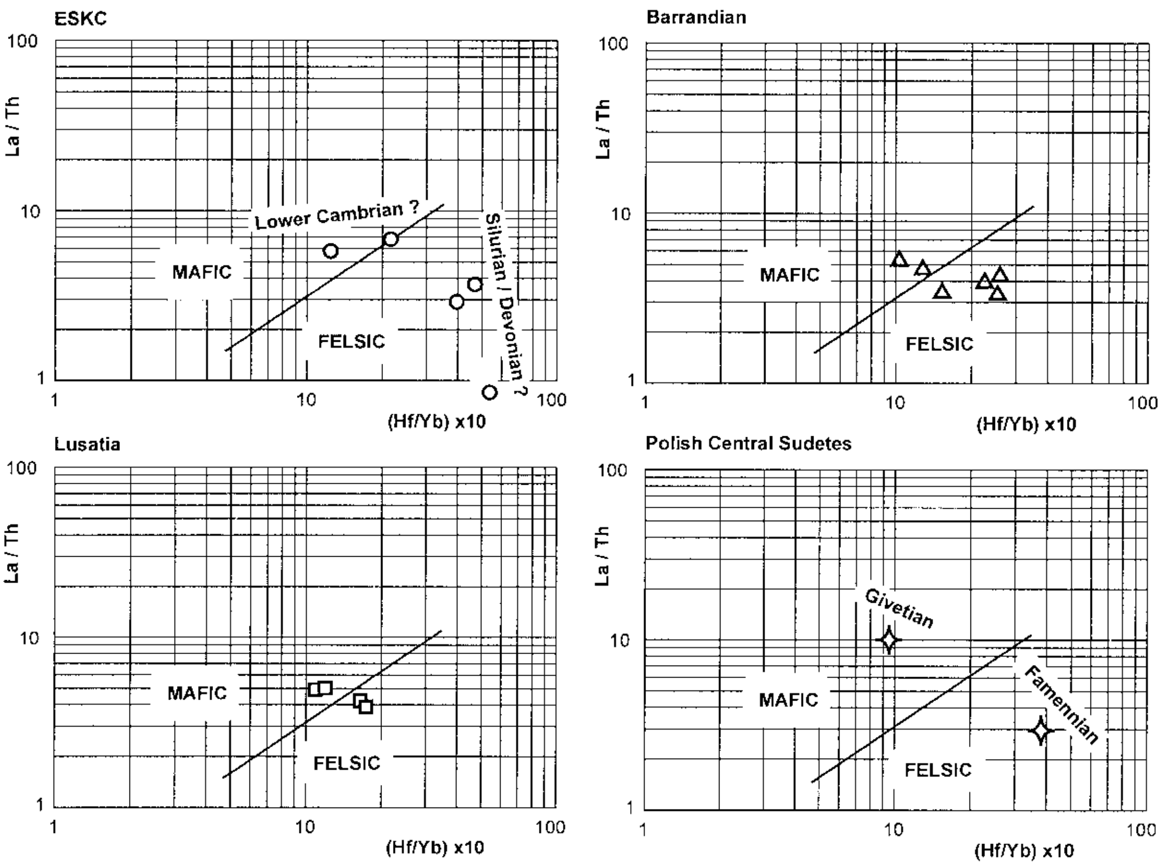


Fig. 7. Diagram (Hf/Yb)×10 vs. La/Th employing representative elements of REE, HFSE, and the least mobile LILE with an approximate boundary between mafic and felsic sources. Data after Floyd (1989), Floyd et al. (1991), Wilson (1993), a.o. The data on insoluble residues from the ESKC metacarbonates and Polish Central Sudetes carbonates display a wide scatter compared to the data on the Barrandian and Lusatian samples.

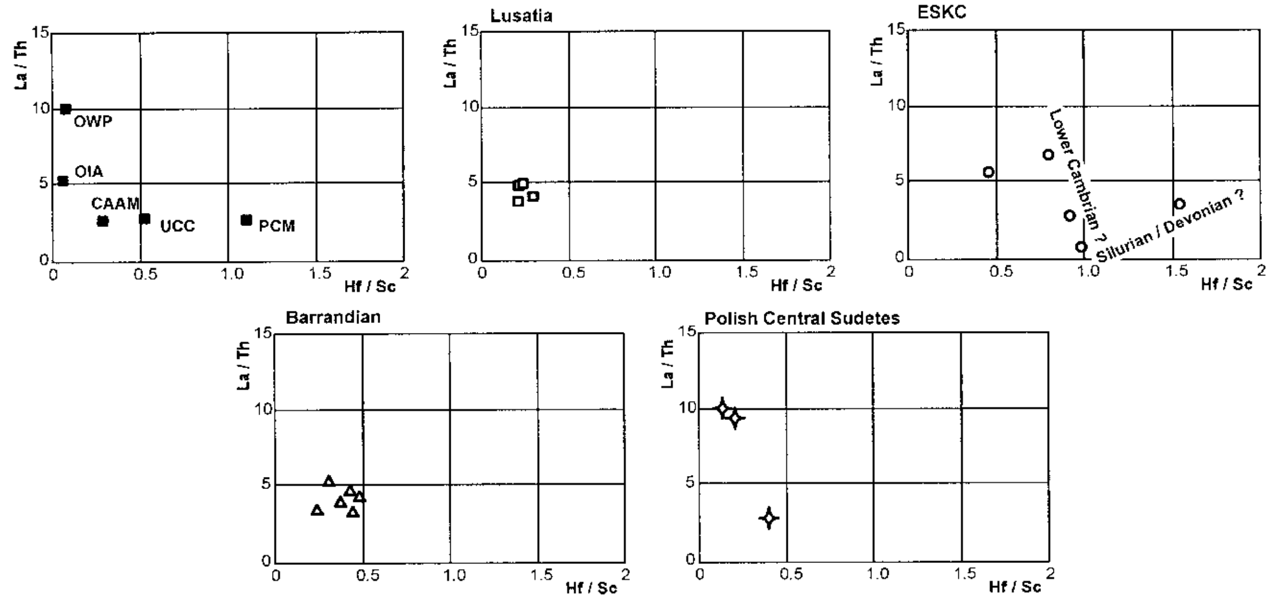


Fig. 8. Insoluble residues from carbonate rocks of the ESKC, Barrandian, Lusatia and Polish Central Sudetes in Hf/Sc vs. La/Th plot. Representative compositions of clastic sediments from various tectonic settings: OWP — oceanic within-plate, OIA — oceanic island-arc, CAAM — continental arc to active continental margin, and PCM — passive continental margin (after Floyd et al. 1991), and UCC — upper continental crust (after Taylor & McLennan 1985).

utilization of this ratio for estimating the original sedimentary conditions or paleogeographical magnafacies.

Discussion

The strong obliteration of primary sedimentary fabrics and alteration of weathering products trapped in carbonates considerably reduce the number of interpretable samples in the ESKC. The exact classification of rock precursors in each of these ESKC carbonate bodies is therefore practically impossible. The analyses of the ESKC marbles provide inspirational jumping-off points for new and more accurate ways of understanding the physical nature of the tectonometamorphically stacked slices and stripes of rocks rather than all-inclusive classification of all samples.

The trace-element geochemistry of dispersed weathering products trapped in carbonates is practically new and connected with many problems. One of the principal problems is the separation of regional influx of "real" CAAM-related material (aquatic suspension from river deltas >> atmospheric deposits) from the "false" CAAM-image of largely averaged background deposits (eolian atmospheric deposits >> aquatic suspensions from river deltas). There is a widespread myth among the geological public, that atmospheric depositions are negligible. This myth is based on present (interglacial) average values for the entire Earth surface area, which are approximately 1.5×10^{-13} $kg \cdot m^{-2} \cdot s^{-1}$ (i.e., ~5 kilograms per square meter and million years). However, it can be easy demonstrated, using the present reviews about deposition of eolian dust and mineral aerosols (Harrison et al. 2001; Mahowald et al. 1999; Tegen & Fung 1995; Duce & Tindale 1991), that areas with carbonate production have a great supply of these atmospheric deposits, which fluctuates in long-term averages from 1.5×10^{-10} to 1.5×10^{-9} $kg \cdot m^{-2} \cdot s^{-1}$ (i.e., ~5 to 50 tons per square meter and million of years). It corresponds, by 20 m/Ma accumulation rate of pure carbonate, for instance, to a maximum possible proportion of this substance (trapped in carbonate), which is equal to 10–50 %. However, this amount is commonly reduced (washed and dissolved) to ½–¼ of the original mass, that is ~2.5–5 to 12.5–25 % of the rock mass.

Accepting that both types of non-carbonate admixtures can represent geochemical traits of source areas, it makes sense to study the deviations from the average clastic sedimentary material of post-Archean age (McLennan 2001). Anyhow it will be impossible to find unchanged igneous compositions in this material (fractionations related to weathering, transport, deposition and diagenesis), at least part of geochemical signatures can be transferred with these weathering products (e.g. Ohr et al. 1994).

In this direction of interpretation, the Lower Cambrian ESKC marbles (Dolní Albeřice and partly also Horní Lánov) and Lusatian oolites (Doberlug-Torgau Syncline) have visible local components, which probably correspond to calc-alkaline (meta)igneous rocks of end-Proterozoic ages. The CAAM character of this material (compare with Bhatia 1985; Bhatia & Crook 1986; Floyd et al. 1991; McLennan et al. 1993) seems to be involved in the double-normalized REE distribution patterns (by PAAS values and by relevant value of Lu_N; Fig. 6A–C). The possible ratio of the local to widely regional and global dispersions (L/G) may fluctuate from 0.25 to 4. A single sample from Polish Central Sudetes (Mały Bożków — Givetian; Fig. 6D) is typical for prevalence of local material. The patterns based on Lochkovian-Emsian limestones of the Barrandian area (Fig. 6B) have extra "phosphate-related deflection" but, in general, again correspond to CAAM. However, the typically decreasing values of Ce and Yb (and especially the absence of micro-lithoclasts and low concentrations of clastic heavy minerals) suggest, that this CAAM character is rather an effect of wide regional averaging, which makes a false semblance that is only similar to CAAM. The possible L/G ratio is only 0.05 to 0.1.

Summarizing all indications, the ESKC Silurian-Devonian insoluble residues differ from their Barrandian counterparts by higher amounts and higher variation of the proximal siliciclastic admixture, where the L/G can increase to values >0.3. The source rocks were of considerable diversity (Poniklá area, for instance — Fig. 6A2). The Poniklá area marbles (ESKC), but particularly the carbonates of the Mały Bożków and Dzikowiec localities (Polish Central Sudetes), reflect a wide array of sources involving mafic to felsic rocks. This may be considered as a direct evidence of synsedimentary (not only late Variscan) unevenness of crustal segment composition. The Kłodzko area also provides evidence about pre-Late Devonian unconformity (Kryza et al. 1999). Practically, the whole possible scale of both inactive (old and exhumed) and synsedimentary settings occur in the Sudetic Terrane Assemblage (from OWP and OIA to continental CAAM and PCM — see Figs. 6 to 8).

The geochemical and lithological characteristics of the carbonate rocks of the ESKC, Lusatia, Polish Central Sudetes and Barrandian — despite many similarities — point to sediment origin in adequately geographically separated basins. The traits observed in the ESKC and Lusatian Cambrian seem to have indirect geodynamic continuation in the Devonian of the Barrandian area. These basins were subsiding on a partly eroded Cadomian CAAM rock suite of northern Gondwanan relevance (Nance & Murphy 1994; Edel & Weber 1995; Kachlík & Patočka 1998b; Keppie & Dostal 1998); the age is Late Vendian, about ~570 Ma (Buschmann et al. 2001). The Cambrian carbonates had to be evolutionarily linked to attenuation and rifting of the West Sudetic Cadomian crust (Kachlík & Patočka 1998b; Dostal et al. 2001). The Silurian-Devonian basins (particularly in Barrandian) attained an advanced stage of basement extension (Patočka et al. 1993; Patočka 2001). On the other hand, the Devonian sedimentary precursors of the ESKC as well as the Polish Central Sudetes differ from any other neighbouring regions with their extremely varying spectrum of sources.

The trace element-REE geochemistry of residues from the West and Central Sudetic limestones and dolomites seems to confirm the significant role of N-Gondwana-pervasive Cambrian-Ordovician intracontinental rifting, which continued with strong Silurian sea-floor spreading (Crowley et al. 2000, or Dostal et al. 2000, 2001). The "oceanization" culminated, during the Devonian, with ocean-floor subduction and amalgamation of the Variscan terrane mosaic (Cymerman et al. 1997; Maluski & Patočka 1997; Pharaoh 1999; Franke et al. 2000; Marheine et al. 2000 in print; Winchester et al. in print).

Conclusions

The marbles in the East and South Krkonoše Complexes (ESKC, N Bohemian Massif, Czech Republic) originated basically from two sedimentary precursors — Cambrian dolomites and Silurian-Early Devonian limestones. The Early Cambrian age (Dolní Albeřice) is shown by an archaeocyath *Erismacoscinus* and probably also by the trilobites *Bonnia* and *Kingaspis*. Abundance of early diagenetically dolomitized oolites and microbialites has lithostratigraphic correlation significance. The occurrence of *Cyrtograptus-Testograptus* graptolite assemblage in slates near Poniklá implies the Wenlockian-Ludlowian age. Possible *Ceratiocaris* and *Nowakia*, both seen with comparative details, suggest that at least part of the marbles between Horní Lánov and Poniklá are of Silurian-Devonian age. The dacryoconarid from Poniklá has apparent similarity to *Nowakia acuaria* and it makes sense to take into consideration the Pragian stratigraphic stage, as the presently youngest biostratigraphic datum in the ESKC. The Silurian-Devonian precursors can be characterized as open-sea calcitic wackestones/packstones and dolomitized packstones/grainstones.

The insoluble residues from the ESKC have REE distributions comparable to PAAS, with decreased abundances (mainly the carbonatic character of residues, but possibly also natural depletion). The analyses of the background sediment trapped in carbonates revealed differences of regional to interregional significance. It implies extensive development of the related N Gondwanan rifting branches with Early-Middle Paleozoic geographical separation of the ESKC, Lusatia, Polish Central Sudetes and Barrandian areas. In a parallel to lithology and fauna, the geochemical features of the Early Cambrian ESKC are apparently similar to Lusatian. These features reflect the "Cadomian orogenic" (calc-alkaline igneous/metaigneous) source rocks, which are traceable even in the Lower Devonian carbonate sediments of the Barrandian area. On the other hand, the Silurian-Devonian features related to the ESKC provide only imperfect links to the Barrandian, the variation of compositions seems to increase toward the Early Devonian — and, the Middle-Late Devonian continuation is absent. In contrast to this, the Polish Central Sudetes (problematic Cambrian, Middle Devonian, Late Devonian) reflect extremely diversified and dynamically developing sources (OWP/OIA-CAAM/UCC-PCM types). Rarely observed lanthanide depletions were found only in the Barrandian, or within variation, also in Polish Central Sudetes.

The information resulting from studies on the ESKC carbonates basically supports the existing opinions about the Cambrian-Ordovician intracontinental rifting (breakup of the N Gondwanan margin) with rapidly developed sea-floor spreading during the Silurian-Devonian times. The ESKC "Lusatian"-type of the Early Cambrian dolostones and "Barrandian"-type of the Silurian-Devonian limestones (by possible absence of Middle-Late Devonian sediments) are additional distinctive characteristics of the Krkonoše-Jizera Terrane.

Acknowledgments: The authors' are thankful for two Academic Grants IAA3013209 "Weathering products" and IAA3111102 "Prevariscan development", with assistance of research frameworks Z3-013-912 (Acad. Sci. Cz.R.), J07/98:143100004 (Masaryk Univ.) and J13/98:113100005 (Charles Univ.). Special thanks are due to O. Elicki and B. Buschmann (Freiberg); S. Mazur, R. Kryza and J. Don (Wroclaw); Ch. Pin (Clermont-Ferrand); F. Debrenne (Paris); W. Franke (Giessen) and P. Kraft, I. Chlupáč, L. Slavík, P. Štorch and R. Mikuláš (Prague) for consulting. Analytical services:

K. Melka-XRD, A. Langrová-EDX and EMP (Inst. Geol., Acad. Sci. Cz.R., Praha), J. Frána-INAA (Inst. Nucl. Phys., Acad. Sci. Cz.R., Řež u Prahy), A. Manda-XRF (Gematest Ltd., Praha).

Appendix

List of sites investigated by means of structural, thin-section and chemical analyses to select reliable places for determination of rock precursors (Fig. 1): ESKC-1 — SSW of Jesenný, Vraštilov; 2 — Jesenný, Old Quarry in village; 3 — Bozkov, Small Quarry at the entrance of the Bozkov Cave; 4 — W of Jesenný, U Staré Vody; 5 — NNE of Bozkov, Brook Junction; 6 — SSW of Jesenný; 7 — SSE of Jesenný; 8 — S of Jesenný; 9 — S of Jesenný, NNW of point 8; 10 — W of Jesenný, Kamenice, Za Papírnou; 11 — the same location, but upper part of the section; 12 — W of Bozkov, Cottage of Kamenice; 13 — NW of Bozkov, Pod Domání; 14 — Horní Maršov, Horní Maršov Cave; 15 — Maršov, 2.2 km S of Horní Maršov Cave; 16 — 2 km NE of Bozkov, U Václavíků; 17A — Poniklá, Poniklá Cave; 17B — Bílá Skála Rock 3 km from Benecko, 3.5 km E of No. 17A; 18 — Křižlice, U Brádlerů, 1.5 km E of Benecko; 19 — Štěpanická Lhota, Old Quarry, 2 km S of Benecko; 20 — Štěpanická Lhota, Water Tank, 2.5 km S of Benecko; 21A — Horní Lánov, Horní Lánov Quarry, Crusher; 21B — Horní Lánov, Horní Lánov Quarry, centre of lower bench; 22 — N of Svoboda nad Úpou, Janské Lázně junction; 23 — Horní Maršov, Water Tank, 0.4 km E of No. 14; 24 — Horní Albeřice, Horní Albeřice Cave close to CZ/PL boundary; 25 — 1.5 km W of Černý Důl.

References

Aleksandrowski P., Kryza R., Mazur S. & Żaba J. 1997: Kinematic data on major strike-slip faults and shear zones in the Polish Sudetes, northeast Bohemian Massif. *Geol. Mag.* 134, 727-739.

Anders E. & Grevesse N. 1989: Abundances of the elements: Meteoritic and solar. *Geochim. Cosmochim. Acta* 53, 197-214.

Bederke E. 1924: Das Devon in Schlesien und das alter der Sudetenfaltung. *Fortschr. Geol. Paläont.* 7, 1, 1-50, 3 pls.

Bendl J. & Patočka F. 1995: The ^{87}Rb-^{86}Sr isotope geochemistry of the metamorphosed bimodal volcanic association of the Rýchory Mts. crystalline complex, West Sudetes, Bohemian Massif. *Geol. Sudetica* 29, 3-18.

Bhatia M.R. 1985: Rare earth element geochemistry of Australian Paleozoic graywackes and mudrocks: provenance and tectonic control. *Sed. Geol.* 45, 97-113.

Bhatia M.R. & Crook K.A.W. 1986: Trace element characteristics of graywackes and tectonic setting discrimination of sedimentary basins. *Contrib. Mineral. Petrol.* 92, 181-193.

Blaker M.R. & Peel J.S. 1997: Lower Cambrian trilobites from North Greenland. *Monogr. Greenland, Geosci.* 35, 1-145.

Bouček B. 1964: The tentaculites of the Bohemia. *Publ. House Czechoslov. Acad. Sci.*, Praha, 1-215, 40 pls.

Bowen H.J.M. 1979: The hydrosphere. In: Environmetal Chemistry of the Elements. *Acad. Press*, London, NewYork and Sydney, 13-29.

Buschmann B., Nasdala L., Jonas P., Linnemann U. & Gehmlich M. 2001: SHRIMP U-Pb dating of tuff-derived and detrital zircons from Cadomian marginal basin fragments (Neoproterozoic) in the northeastern Saxothuringian Zone (Germany). *Neu. Jb. Geol. Paläont., Mh.* 6, 321-342.

Chaloupský J. 1958: Geological and petrographic setting Jizera River Valley between Harachov and Dolní Rokytnice (in Czech). *Rozpr. Ústř. Úst. Geol., Sb.* 24, 189-236.

Chaloupský J. et al. 1989: Geologie Krkonoš a Jizerských hor. *Nakl. Ústř. Úst. geol.*, Praha, 1-288.

Chlupáč I. 1953: Founds of graptolites in unmetamorphosed Silurian near Železný Brod in Krkonoše Piedmont area (in Czech). *Věst. Ústř. Úst. Geol.* 28, 213-215.

Chlupáč I. 1993: Stratigraphic evaluation of some metamorphic units in the N part of the Bohemian Massif. *Neu. Jb. Geol. Paläont., Abh.* 188, 363-388.

Chlupáč I. 1997: Palaeozoic ichnofossils in phyllites near Železný Brod, northern Bohemia. *J. Czech Geol. Soc.* 42, 1-2, 75-94.

Chlupáč I. 1998: New paleontological finds in the western part of the Krkonoše-Jizerské Hory Mts.: metamorphics and their impact on stratigraphical and tectonical concepts. *Geolines* 6, 29-30.

Chlupáč I. & Hladil J. 1992: New Devonian occurrences in the Ještěd Mts., North Bohemia. *Čas. Mineral. Geol.* 37, 3, 185-191.

Collins A.S., Kryza R. & Zalasiewicz J.A. 2000: Macrofabric fingerprints of the Late Devonian-Early Carboniferous subduction in the Polish Variscides. *J. Geol. Soc. London* 157, 283-288.

Crowley Q.G., Floyd P.A., Winchester J.A., Franke W. & Holland J.G. 2000: Early Paleozoic rift-related magmatism in Variscan Europe: fragmentation of the Armorican Terrane Assemblage. *Terra Nova* 12, 171-180.

Crowley Q.G., Patočka F. & Parrish R.R. 2001: The ancestry and affinity of Central Europe: New U-Pb (LA-PIMMS) ages of inherited zircons from Early Palaeozoic granitoids of the W Sudetes, NE Bohemian Massif. *Abstr. Joint Meeting Europrobe TESZ, TIMPEBAR, URALIDES and SW-Iberia Proj-s, Ankara, 30 Sept. to 2 Oct., 2001*, 11-12.

Cymerman Z., Piasecki M.A.J. & Seston R. 1997: Terranes and terrane boundaries in the Sudetes, northeast Bohemian Massif. *Geol. Mag.* 133, 717-725.

Dostal J., Patočka F. & Pin Ch. 2000: Early Paleozoic intracontinental rifting and early sea-floor spreading in the central West Sudetes (Bohemian Massif): geochemical and Sr-Nd isotopic study on metavolcanic rocks of the East Krkonoše Complex. *Geolines* 10, 19-20.

Dostal J., Patočka F. & Pin Ch. 2001: Middle/Late Cambrian intracontinental rifting in the central West Sudetes, NE Bohemian Massif (Czech Republic): geochemistry and petrogenesis of the bimodal metavolcanic rocks. *Geol. J. (Manchester)* 36, 1-17.

Duce R.A. & Tindale N.W. 1991: Atmospheric transport of iron and its deposition in the ocean. *Limnol. Oceanogr.* 36, 1715-1726.

Edel J.B. & Weber K. 1995: Cadomian terranes, wrench faulting and thrusting in the central Europe Variscides: geophysical and geological evidence. *Geol. Rdsch.* 84, 412-432.

Elicki O. 1999: Beitrag zur Lithofazies und zur Lithostratigraphie im Unterkambrium von Doberlug-Torgau. *Freib. Forsch.-H., Paläont., Stratigr., Fazies* C481/7, 107-119.

Elicki O. & Debrenne F. 1993: The Archaeocyatha of Germany. *Freib. Forsch.-H., Paläont., Stratigr., Fazies* C450/1, 3-41.

Elicki O. & Shinaq R. 2000: Kambrische Lagunen-Karbonate vom südlichen Toten Meer (Wadi Tayan, Jordanien). *Freib. Forsch.-H., Paläont., Stratigr., Fazies* C490/8, 51-66.

Encarnación J., Powell A.J. & Grunow A.M. 1999: A U-Pb age for the Cambrian Taylor Formation, Antarctica: Implications for the Cambrian Time Scale. *J. Geol.* 107, 497-504.

Erickson S.G. 1994: Deformation of shale and dolomite in the Lewis Thrust-Fault Zone, Northwest Montana, USA. *Canad. J. Earth Sci.* 31, 9, 1440-1448.

Fisler D.K. & Cygan R.T. 1999: Diffusion of Ca and Mg in calcite. *Amer. Mineral.* 84, 9, 1392-1399.

Floyd P.A. 1989: Geochemical features of intraplate oceanic plateau basalts. In: Saunders A.D. & Norry M.J. (Eds.): Magmatism in the Ocean Basins. *Geol. Soc. London, Spec. Publ.* 42, 215-230.

Floyd P.A., Shail R., Leveridge B.E. & Franke W. 1991: Geochemistry and provenance of Rhenohercynian sandstones: implications for tectonic environment discrimination. In: Morton A.C., Todd S.P. & Haughton P.D.W. (Eds.): Developments in Sedimentary Provenance Studies. *Geol. Soc. London, Spec. Publ.* 57, 173–188.

Franke W. 2000: The suture zone between Avalonia and the Armorican Terrane Assemblage in Central Europe. In: Variscan-Appalachian dynamics: the building of the Upper Palaeozoic basement. *Basement Tectonics 15, La Coruña, Spain, Program and Abstracts*, 114–116.

Franke W., Żelaźniewicz A., Porębski S.J. & Wajsprych B. 1993: Saxothuringian zone in Germany and Poland: differences and common features. *Geol. Rdsch.* 82, 583–599.

Furnes H., Kryza R., Muszynski A., Pin C. & Garmann L.B. 1994: Geochemical evidence for progressive, rift-related early Palaeozoic volcanism in the western Sudetes. *J. Geol. Soc. London* 151, 91–109.

Galle A. & Chlupáč I. 1976: Finds of corals in the metamorphic Devonian of the Ještědské pohoří Mountains. *Věst. Ústř. Úst. Geol.* 51, 123–128.

Gehmlich M., Linnemann U., Tichomirova M., Lützner H. & Bombach K. 1997: Die Bestimmung des Sedimentationsalters cadomischer Krustenfragmente im Saxothuringikum durch die Einzelzirkon-Evaporationsmethode. *Terra Nostra* 97, 5, 46–49.

Geyer G. & Elicki O. 1995: Lower Cambrian trilobites from the Görlitz Synclinorium (Germany) — review and new results. *Paläont. Z.* 69, 1–2, 87–119.

Geyer G. & Landing E. 2001: Middle Cambrian of Avalonian Massachusetts: Stratigraphy and correlation of the Braintree trilobites. *J. Paleont.* 75, 1, 116–135.

Girty G.H., Barber R.W. & Knaack 1993: REE, Th and Sc evidence for depositional setting and source rock characteristics of the Quartz Hill chert, Sierra Nevada, California. In: Johnsson M.J. & Basu A. (Eds.): Processes controlling the composition of clastic sediments. *Geol. Soc. Amer., Spec. Pap.* 284, 109–120.

Gürich G. 1929: *Silesicaris* von Leipe und die Phyllokariden überhaupt. *Mitt. Mineral.-Geol. Staatinst. Hamburg* 1929, 1–12.

Harrison S.P., Kohfeld K.E., Roelandt C. & Claquin T. 2001: The role of dust in climate changes today, at the last glacial maximum and in the future. *Earth-Science Reviews* 54, 43–80.

Hladil J., Mazur S., Galle A. & Ebert J.R. 1999: Revised age of the Mały Bożków limestone in the Klodzko metamorphic unit (early Givetian, late Middle Devonian): implications for the geology of the Sudetes, SW Poland. *Neu. Jb. Geol. Paläont., Abh.* 211, 3, 329–353.

Horný R. 1964: New graptolites from unmetamorphosed Silurian in Krkonoše Piedmont area. *Čas. Nár. Muz., Odd. Přírodověd.* 133, 4, 224 (in Czech).

Hoth K. 2000: Diskussionsbeitrag zur lithostratigraphischen Gliederung der Metasedimente im südlichen und östlichen Krkonoše/Karkononosze. *Z. Geol. Wiss.* 28, 211–227.

KachlíkV. & Kozdroj W. 2001: Ještěd Range Unit. In: Kozdroj W., Krentz O. & Opletal M. (Eds.): Comments on the Geological map Lauzitz-Jizera-Karkonozse (without Cenozoic sediments). *Sächsisches Landesamt für Umwelt und Geologie/Bereich Boden und Geologie*, Freiberg, *Panstvowy Instytut Geologiczny*, Warzsawa, *Český geologický ústav*, Praha, 27–31.

Kachlík V. & Patočka F. 1998a: Lithostratigraphy and tectonomagnetic evolution of the Železný Brod Crystalline Unit: some constraints for the palaeotectonic development of the W Sudetes (NE Bohemian Massif). In: Svojtka M. (Ed.): 3rd Meeting of the Czech Group for Tectonic Studies. *Geolines* 6, 34–35.

Kachlík V. & Patočka F. 1998b: Cambrian/Ordovician intracontinental rifting and Devonian closure of the rifting generated basins in the Bohemian Massif realms. *Acta Univ. Carol., Geol.* 42, 433–441.

Kachlík V. & Patočka F. 2001: Late Devonian to Early Carboniferous bimodal volcanic rocks of the Ještěd Range Unit (W Sudetes): constraints on the Devonian development of the Variscan orogenic wedge. *Geolines* 13, 74–75.

Kachlík V., Patočka F. & Fajst M. 2002: Sheared metagranitoids in the Ještěd Range Mts.: the role in the westward propagation of the Variscan orogenic wedge in the West Sudetes. *Geolines* (in print).

Kachlík V., Patočka F., Marheine D. & Maluski H. 1999: The deformed metagranites of the Krkonoše-Jizera terrane: controversies between protolith ages and stratigraphy. *Abstracts of the PACE mid-term review and 4th PACE network meeting, Geological Institute, University of Copenhagen, Denmark* (Copenhagen), October 9-10, 1999, 21–22.

Keppie D. & Dostal J. 1998. Terrane transfer between eastern Laurentia and northwestern Gondwana: the place of the Teplá-Barrnadian, Bohemian Massif. *Acta Univ. Carol., Geol.* 42, 447–450.

Koliha J. 1929: Upper Devonian in Ještěd Mountain Range. *Věst. Stát. Geol. Úst.* 5, 4–5, 286–292 (in Czech).

Konzalová M. & Hrabal J. 1998: Microfossils from the graphite phyllites of the NE Bohemian Crystalline Complex. *Věst. Čes. Geol. Úst.* 73, 79–84.

Kozdroj W., Cymerman Z., Kachlík V. & Opletal M. 2001: Karkonozse-Jizera Region. In: Kozdroj W., Krentz O. & Opletal M. (Eds.): Comments on the Geological map Lauzitz-Jizera-Karkonozse (without Cenozoic sediments). *Sächsisches Landesamt für Umwelt und Geologie/Bereich Boden und Geologie*, Freiberg, *Państvowy Instytut Geologiczny*, Warzsawa, *and Český geologický ústav*, Praha, 22–27.

Kröner A., Hegner E., Hammer J., Haase G., Bielicky K.H., Krauss M. & Eidam J. 1994: Geochronology and Sm-Nd systematics of Lusatian granitoids: significance for the evolution of the Variscan orogen in east-central Europe. *Geol. Rdsch.* 83, 357–376.

Krutský N. 1968: Report on survey of Krkonoše Mountains marble deposits. *Ústř. Úst. Geol., Zpr. Geol. Výzk.* 1967, 60–61 (in Czech).

Kryza R., Mazur S. & Aleksandrowski P. 1999: Pre-Late Devonian unconformity in the Kłodzko area excavated: a record of Eo-Variscan metamorphism and exhumation in the Sudetes. *Geol. Sudetica* 32, 127–137.

Mahowald N., Kohfeld K.E., Hansson M., Balkanski Y., Harrison S.P., Prentice I.C., Rodhe H. & Schulz M. 1999: Dust effect of climate change on dust storm activity in Australia during the Last Glacial Maximum. *Geomorphology* 17, 263–271.

Maluski H. & Patočka F. 1997: Geochemistry and 40Ar-39Ar geochronology of the mafic metavolcanics from the Rýchory Mts. complex (W Sudetes, Bohemian Massif): palaeotectonic significance. *Geol. Mag.* 133, 703–716.

Marheine D., Kachlík V., Patočka F., Maluski H. & Żelaźniewicz A. 2000: Variscan polyphase tectonothermal record in the West Sudetes (Bohemian Massif) — deduced from Ar-Ar ages. *15th Internat. Conf. Bas. Tecton., La Coruña*, 254–257.

Marheine D., Kachlík V., Maluski H., Patočka F. & Żelaźniewicz A. (in print): The Ar-Ar ages from the West Sudetes (NE Bohemian Massif): constraints on the Variscan polyphase tectonothermal development. *J. Geol. Soc. London, Spec. Pap.*

Matthews A., Lieberman J., Avigad D. & Garfunkel Z. 1999: Fluid-rock interaction and thermal evolution during thrusting of an Alpine metamorphic complex (Tinos island, Greece). *Contrib. Mineral. Petrol.* 135, 2-3, 212–224.

Mazur S. & Kryza R. 1999: Mylonites in the Kłodzko metamorphic unit — a record of pre-Late Devonian dextral transpression in the West Sudetes. *Geolines* 10, 51–52.

McLennan S.M. 2001: Relationships between the trace element composition of sedimentary rocks and upper continental crust.

Geochem., Geophys., Geosyst. 2, 1–29.

McLennan S.M. & Taylor S.R. 1991: Sedimentary rocks and crustal evolution: tectonic setting and secular trends. *J. Geol. (Chicago)* 99, 1–21.

McLennan S.M., Hemming S., McDaniel D.K. & Hanson G.N. 1993: Geochemical approaches to sedimentation, provenance and tectonics. In: Johnsson M.J. & Basu A. (Eds.): Processes controlling the composition of clastic sediments. *Geol. Soc. Amer., Spec. Pap.* 284, 21–40.

Mistiaen B. 1984: Disparition des Stromatopores paléozoïques ou survie du groupe: hypothèse et discussion. *Bull. Soc. Géol. France* 26, 6, 1245–1250.

Nance D. & Murphy J.B. 1994: Contrasting basement isotopic signatures and the palinspastic restoration of peripheral orogens: Example from the Neoproterozoic Avalonian-Cadomian belt. *Geology* 22, 617–620.

Nance W.B. & Taylor S.R. 1976: Rare earth patterns and crustal evolution, I. Australian post-Archean sedimentary rocks. *Geochim. Cosmochim. Acta* 40, 1539–1551.

Narębski W. 1994: Lower to Upper Paleozoic tectonomagmatic evolution of NE part of the Bohemian Massif. *Zb. Geol. Paläont.* 9, 10, 961–972.

Ohr M., Halliday A.N. & Peacor D.R. 1994: Mobility and fractionation of rare earth elements in argillaceous sediments; implications for dating diagenesis and low-grade metamorphism. *Geochim. Cosmochim. Acta* 58, 1289–1312.

Oliver G.J.H., Corfu F. & Krogh T.E. 1993: U-Pb ages from SW Poland: evidence for a Caledonian suture zone between Baltica and Gondwana. *J. Geol. Soc. London* 150, 355–369.

Palmer A.R. 1964: An unusual Lower Cambrian trilobite fauna from Nevada. *Contrib. Paleont., Geol. Surv. Prof. Pap.* 483-F, 1–13, pls. 1–3.

Patočka F. 2001: Geochemistry of the Early Palaeozoic siliciclastic sediments of the Barrandian (Bohemian Massif, Czech Republic): provenance and palaeotectonic implications. *Abstr. Conf. Early Palaeoz. Palaeogeogr. Palaeobiogeogr. W Europe N Africa, Lille,* 23–29 Sept. 2001, 1–52.

Patočka F. & Smulikowski W. 2000: Early Palaeozoic intracontinental rifting and incipient oceanic spreading in the Czech/Polish East Krkonoše/Karkonosze Complex, West Sudetes (NE Bohemian Massif). *Geol. Sudetica* 33, 1–15.

Patočka F., Kachlík V. & Fajst M. 2000: Mafic-felsic to mafic-ultramafic Early Palaeozoic magmatism of the West Sudetes (NE Bohemian Massif): the South Krkonoše Complex. *Z. Geol. Wiss.* 28, 177–210.

Patočka F., Vlašímský P. & Blechová K. 1993: Geochemistry of Early Paleozoic volcanics of the Barrandian Basin (Bohemian Massif, Czech Republic): implications for paleotectonic reconstructions. *Jb. Geol. B.-A. (Wien)* 136, 871–894.

Perner J. 1919: Silurian in Krkonoše Mountains. *Čas. Nár. Muz. v Praze* 93, 33–34 (in Czech).

Pharaoh T.C. 1999: Palaeozoic terranes and their lithospheric boundaries within the Trans-European Suture Zone (TESZ): a review. *Tectonophysics* 314, 17–41.

Pin Ch., Mierzejewski M.P. & Duthou J.L. 1987: Rb/Sr isochron age of the Karkonosze granite from quarry Szklarska Poręba Huta and determination of its $^{87}Sr/^{86}Sr$ initial ratio. *Przegląd geologiczny* 35, 512–517.

Prantl F. 1948: Paleontological investigations of limestones in Železný Brod and Vrchlabí areas. *Věst. Stát. Geol. Úst.* 23, 178–180 (in Czech).

Sandberg P.A. 1983: An oscillating trend in Phanerozoic non-skeletal carbonate mineralogy. *Nature* 305, 19–22.

Skowronek A. & Steffahn J. 2000: The age of the Kauffung Limestone (W Sudetes, Poland) — a revision due to new discovery of microfossils. *Neu. Jb. Geol. Paläont., Mh.* 2, 65–82.

Svoboda F. 1955: Limestones of the Krkonoše and Jizerské hory Mountains. *Geotechnica (Praha)* 21, 7–67, 9 photo-pls., 16 encls (in Czech).

Taylor S.R. & McLennan S.M. 1985: The continental crust: its composition and evolution. *Blackwell Sci. Publ.,* Oxford, 1–312.

Tegen I. & Fung I. 1995: Contribution to the atmospheric mineral aerosol load from land surface modification. *J. Geophys. Res.* 100, 18707–18726.

Timmermann H., Parrish R.H., Noble S.R., Kryza R. & Patočka F. 1999: Single cycle Variscan orogeny inferred from new U-(Th-)Pb data from the Sudetes mountains in Poland and the Czech Republic. *Abstracts of the PACE mid-term review and 4th PACE network meeting*, Denmark, Copenhagen, October 9–10, 1999, 1–24.

Walter H. 2000: Neufunde von sphaerischen Mikrofossilien (?Muellisphaerida, ?Mazuelloiden) im Gebiet des südlichen Krkonoše und in der Lausitz. *Z. Geol. Wiss.* 28, 1–2, 71–87.

Watznauer A. 1934: Obersilurische Graptolithen aus dem Jeschkengebirge. *Firgenwald (Liberec)* 7, 1–70.

Wilson M. 1993: Igneous petrogenesis. *Chapmann & Hall,* London, 1–466.

Winchester J.A. & The PACE Network Team (contract ERBFMRX-CT97-0136) incl. Belka Z., Patočka F. & Kachlík V. (in print): A new interpretation of the Palaeozoic amalgamation of the Central Europe, based on new geological and geophysical investigations. *J. Geol. Soc. London, Spec. Pap.*

Żelaźniewicz A. 1997: The Sudetes as a Palaeozoic orogen in central Europe. *Geol. Mag.* 133, 691–702.

Zikmundová J. 1964: Founds of conodonts in Ještěd Mountain Range. *Věst. Ústř. Úst. Geol.* 39, 6, 455–457 (in Czech).