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Rauhwackized carbonate tectonic breccias in the West Carpathian nappe edifice: introductory remarks and preliminary results

DUŠAN PLAŠIENKA[1] & JÁN SOTÁK[2]

[1]Geological Institute of the Slovak Academy of Sciences, Dúbravská 9, 842 26 Bratislava, Slovakia
[2]Geological Institute of the Slovak Academy of Sciences, Severná 5, 974 01 Banská Bystrica, Slovakia

Abstract. Based on the provenance of diagnostic clasts, four types of rauhwackized carbonate tectonic breccias occuring at the West Carpathian cover nappe soles are distinguished and characterized. Four types are combinations of two most distinctive signatures of the clast provenances: their derivation from either the nearby juxtaposed carbonate complexes (intraclasts) or the distant sources (extraclasts), and from either the hangingwall or footwall units. Some consequences for the thrusting mechanisms, e.g. subaqueous vs. subaerial, are also discussed.

Key words: Central Western Carpathians, cover nappe soles, carbonate tectonic breccias, emplacement mechanisms

Introduction

Carbonate tectonic breccias are penetratively (in the meso-scale) brittlely deformed original sedimentary carbonates (limestones and dolostones). Carbonate tectonic breccias are formed through fracturing and crushing with dominant role of percolating solutions under intricate fluid regimes by multiple pressure solution, chemical alteration, recrystallization and precipitation processes. They are influenced also by subrecent recalcification, chemical alterations, leaching, weathering with concentration of Fe-hydroxides causing the typical ochre colour and karstification. The end members of these processes are rocks designated by German terms "Rauhwacke" or "Zellendolomit" (e.g. CORNELIUS, 1927; MÜLLER, 1982; LEINE, 1971), French "cornieules" or "cargneules" (e.g. MASSON, 1972; WARRAK, 1974; JEANBOURQUIN, 1988), and Italian "calcare cavernoso" (MASI & TUCCI, 1993; CARTER et al., 1994).

In the international structural geological literature, the problematics of carbonate tectonites has been widely discussed during the last two decades, forced by the introduction of new methodical procedures. In the case of study of rauhwackes, the classical petrographic observations in thin sections (e.g. LEINE, 1971; MASSON, 1972; WARRAK, 1974; MÜLLER, 1982; JEANBOURQUIN, 1988) have been improved by studies of cathodoluminiscence, fluid inclusions and stable isotopes (RYE & BRADBURY, 1988; BURKHARD & KERRICH, 1988; AMIEUX & JEANBOURQUIN, 1989; CARTER ET AL., 1992; MASI & TUCCI, 1993; CROS et al., 1996, etc.). These works have clearly shown that rauhwackes may provide important information about the rheological, pressure and fluid regimes operating during their formation, and even the age constraints of their emplacement event can be defined.

In the Western Carpathian literature, only short notes about rauhwackes can be found in papers by MIŠÍK (1972), PLAŠIENKA (1981), and JAROSZEWSKI (1982), who emphasized the extraordinary importance of the fluid-driven deformation processes in thrust terrains. The role of fluids in the emplacement mechanisms of the Carpathian cover nappes was discussed also by JACKO and SASVÁRI (1990).

The present paper aims at tectonic systematization of rauhwackized carbonate tectonic breccias and at the formulation of a working hypothesis of their origin and significance for the nappe tectonics. This hypothesis should serve as a basis for the choice of the most appropriate research methods and analytical procedures which might provide new information about the genesis of these so important, but often disregarded rocks.

Rauhwackes confined to stratigraphic successions

Rauhwackes are usually considered to be rocks formed from carbonate (mainly dolostone, less limestone) and associated sulphate (gypsum or anhydrite), and possibly also halite precursors. The extreme competence contrast and strain rate differences between these two rock types result in brittle brecciation of dolomitic and ductile flow of sulphate rocks even at temperatures below 100° C (MÜLLER, 1982; SCHMID, 1982). Moreover, the volume changes during the gypsum to anhydrite and vice-versa transformations contribute significantly to the brecciation of the accompanying carbonate rocks, enhanced also by hydraulic fracturing ini-

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tiated by fluid overpressure in the system trapped in non-permeable wall rocks (shales). These rauhwackes may be termed dilation (collapse and/or expansion) breccias. Layer-parallel shearing along weak evaporitic horizons accelerated the development of rauhwackes. In spite of the content of various rock fragments (carbonates, shales), these always represent only the local intraformation or wall sediments. Both monomict and polymict rauhwackes in the sense of LEINE (1971) are present.

Evaporitic dolomite- and gypsum-bearing sedimentary sequences are commonly present amidst Permoscythian or Norian (Keuper) red beds of several Western Carpathian units. Rauhwackes often occur on peripheries of sulphate bodies and, if sulphate is completely dissolved, they resemble breccia layers of originally sedimentary origin (e.g. MAHEĽ & BIELY, 1956 - regression breccias). We have investigated intrastratal dilation breccias in the Carpathian Keuper formation of the Krížna nappe at the locality Rybô in the Veľká Fatra Mts. and in the Permoscythian evaporites from the borehole VŠDL-18, Špania Dolina.

Rauhwackized tectonic breccias

Since gypsum- and/or anhydrite-bearing rocks concentrate deformation due to high strain rates, evaporitic formations often serve as décollement horizons. Large-scale décollements result in generation of allochthonous units with soles commonly composed of rauhwackized carbonate breccias, the witnesses of former evaporites. Thrust planes, as zones of high shear stresses, evidently need a weak "lubricant" layer to accomodate most of the shearing strain during overthrusting. Evaporites and rauhwackes, especially overpressured, are ideal rocks for such a role. In the Western Carpathians, evaporite-containing décollement layers occur in the Upper Permian red-bed sequences (Silicic nappes), Upper Scythian variegated shales (Hronic and Fatric nappes) and Upper Triassic Keuper formation (Fatric units). Nevertheless, some nappes are floored by carbonate tectonic breccias which obviously were formed at the expense of footwall or hangingwall non-evaporitic carbonate complexes (though they can include originally evaporitic matrix as well), and they even contain "exotic" fragments derived from rock complexes currently not present in the nearby structure.

Based on the composition and provenance of the rock fragments in the nappe-sole rauhwackes, their tentative classification from the tectonic point of view is presented (Tab. 1, Fig. 1). The four types distinguished are not ultimately defined, and transitional varieties commonly occur in the field. Nevertheless, the presence of some diagnostic clasts might, in our opinion, contribute to the tectonic interpretation of their origin and of the affiliation, transport direction and mechanisms of the overlying nappe unit.

The type **1A** contains dominantly intraclasts from the juxtaposed hangingwall complexes, mostly carbonates. They usually form the nappe bases, especially where the nappe sole lacks non-carbonatic complexes. In the Western Carpathians, these are mainly frontal parts of Fatric and Hronic nappes (not floored by Permoscythian clastic formations), or overthrust planes of internal partial nappes. Evaporites often played a negligible role in the formation of the 1A-type rauhwackes. Moreover, we have sometimes observed original unaltered carbonate cataclastic breccias at bases of the Choč nappe (Majerova skala hill, Veľká Fatra Mts.) and the Fatric Bujačí subunit (Belianske Tatry Mts.). These are monomict dolocataclasites to mylonites showing indistinct semiductile flow foliation and lineation with dolostone porphyroclasts rimmed by pressure shadows. They were formed by brittle crushing and grain-size reduction up to rupturing of individual crystals to form a "pseudomicrite". Other 1A-type rauhwackes are ordinary cavernous calcitic rocks (boxwork-rauhwacke) with dedolomitized and leached original dolostone clasts.

All rauhwacke types described were fundamentally formed by brittle fragmentation of carbonate precursors, their possible mixing with highly mobile sulphates (usually calcitized or leached later - WARRAK, 1974), chemical alterations by percolating fluids, possibly overpressured (hydraulic fracturing - MASSON, 1972) and by late dissolution. High pore-fluid pressure might have led to "hydrotectonic" phenomena (JAROSZEWSKI, 1982), such as complete dissolution of the carbonate breccia bodies in the course of thrusting resulting in a "macrostylolite" contact (Fig. 1) between carbonates of the autochthonous Tatric substratum and allochthonous Krížna nappe (Tatra Mts. - JAROSZEWSKI, 1982).

The **1B** rauhwackes contain distinctive extraclasts obviously not derived from the actually juxtaposed footwall and hangingwall complexes (though these can be present as well). Based on their compositions, the provenance of some unaltered clasts may be inferred. In the case of the sole of the Hronic Choč nappe on northern slopes of the Nízke Tatry Mts., the rauhwackized carbonate breccias are wedged between the underlying low-grade metamorphosed Neocomian marlstones of the north Veporic-Fatric Veľký Bok unit and the overlying, unmetamorphosed Upper Paleozoic clastic formations of the Hronic Ipoltica group (Fig. 1). However, the prevalence of carbonate clasts is formed by unmetamorphosed Triassic dolostones and limestones, which otherwise occur in a much more higher structural position above the up to several thousands of metres thick Ipoltica group. This fact may be tentatively explained in two ways: (1) rauhwackized breccias represent the lower sheared-off limb of the Choč fold-nappe, or tectonically reduced and brecciated lower Hronic partial unit; (2)

Tab. 1 An attempt to the tectonic classification of carbonate crush breccias and rauhwackes occuring at the West Carpathian cover nappe soles, based on the composition and inferred provenance of the most distinctive rock fragments. Examples are depicted in Fig. 1.

TYPE	INFERRED PROVENANCE OF DIAGNOSTIC CLASTS IN TECTONIC BRECCIAS	EXAMPLES
1A	internal hangingwall-derived rocks fragments from the immediately overlying complexes (mostly carbonates)	soles of the Krížna and Choč nappes (without Ipoltica)
1B	external hangingwall-derived rocks fragments from distant complexes of the nappe unit (mostly carbonates)	sole of the Choč nappe with the Ipoltica group
2A	internal footwall-derived rocks fragments of the immediate substratum (mostly metacarbonates)	soles of the Muráň and Drienok nappes
2B	external footwall-derived rocks "exotic" fragments or slices of metamorphic and ophiolitic complexes	soles of the Stratená and Silica nappes

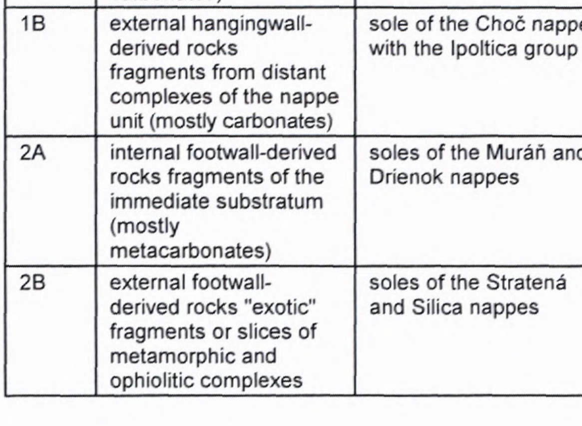

Fig. 1. Schematic position of rauhwackized, dominantly carbonate tectonic breccias at soles of the Carpathian superficial nappes. Not to scale. G – Gemeric units. Important fragments in rauhwackes: C – unmetamorphosed carbonates (hangingwall-derived), M – metamorphosed carbonates (footwall-derived), S – serpentinite, R – radiolarite. Note a considerable structural discordance at the rauhwacke vs. substratum contact in the upper three examples.

breccias are of tectono-sedimentary origin - formed from the carbonate erosional debris of the overthrust allochthonous sheet deposited in its advancing front, later overridden by the lowermost nappe parts and crushed and altered as other carbonate tectonic breccias. At the time being, we prefer the second possibility, as the first one does not correspond to the overall structure of the Hronic nappe system.

The **2A** type carbonate breccias have been observed at the base of the Silicic Muráň nappe. They contain various clasts, among them fragments of their immediate substratum - the strongly metamorphosed and ductilely strained Middle and Upper Triassic limestones, and scarcely also Lower Triassic quartzites, of the footwall Veporic Foederata cover unit. In addition to these, clasts of Scythian shales, Triassic unmetamorphosed carbonates, dark metamorphic slates of unknown provenance and other rocks occur as well. PLAŠIENKA (1981) reported also clasts of speleothems. MILOVSKÝ (1996) found authigenic potassium feldspars in the matrix of rauhwackes. The genesis of 2A rauhwackes was, at the starting phase of their development, probably connected with basal truncation and disintegration of footwall carbonate rocks, which possibly built up a subaerial rugged karstified relief in the time of thrusting of Silicic nappes.

Another type of 2A rocks are rauhwackized carbonate breccias occuring below the Drienok nappe. They have been recently interpreted as Upper Cretaceous to Paleocene sedimentary breccias, later overridden by the south-vergent Drienok nappe (SLAVKAY & ROHÁLOVÁ, 1993). However, they exhibit features typical for other rauhwackized carbonate tectonites and belong probably to our 2A type, being dominantly composed of clasts of the underlying Triassic carbonates of the Choč unit and, less frequently, of slightly metamorphosed rocks of the Lučatín (Veľký Bok) unit from its deeper substratum. Hangingwall-derived clasts are also occurring. These breccias might have had sedimentary precursors deposited in karstic depressions and later mixed with tectonically originated material. Such karst rauhwackes were described by JEANBOURQUIN (1988).

The last, **2B** type rauhwacke is distinctive due to occurences of rock fragments derived from "exotic" units, currently not present either in footwall or hangingwall complexes. However, based on regional assumptions, they are inferred to come from distant footwall units. Clasts and blocks of ophiolites, predominantly serpentinites, less frequently marbles and radiolarites, are of special interest. They are chaotically distributed in a rauhwacke matrix. 2B-type rocks approach some characteristics of ophiolite mélanges. In the case of being incorporated into evaporitic matrix, they have been termed "salinar mélange" by KOZUR (1991). These rocks occur at soles of higher Juvavic nappes in the Northern Calcareous Alps ("Haselgebirge") and at soles of the Silicic Stratená (cf. JAROŠ et al., 1981) and Silica-Aggtelek nappes (Perkupa formation). Ophiolitic rocks, especially highly mobile serpentinites, were incorporated into basal carbonate-sulphate nappe tectonites probably during the translation of Silicic nappes across or along an ophiolitic suture in their substratum.

Discussion and conclusion

The above outlined characteristic features and distribution of the Western Carpathian rauhwackes confined to the overthrust planes of far-reaching superficial cover nappes indicate that the types distinguished can be attributed to the individual nappe systems or their parts. The types 1A, involving preferably hangingwall-derived intraclasts, are most frequent in frontal parts of the Fatric and Hronic nappes and at bases of their internal subunits. However, they are often completely dissolved to form a large-scale stylolitic contact of apparently non-tectonic origin. This indicates high activity of interstitial fluids bound to the breccia bodies and their more-or-less free possibility to release in the course of thrusting. In spite of its escape, the fluid influx seems not to have been limited. It might be speculated that continuous fluid supply was fed by compactional dewatering of the underlying Tatric and/or Fatric mid-Cretaceous flysch sediments deposited immediately before being loaded by the overriding nappes. This would indicate a subaqueous character of the nappe emplacement. Stable isotope studies should either confirm or deny this assumption.

The 1B rauhwackes with hangingwall-derived extraclasts have been found below the Choč nappe floored by the Ipoltica group. Their probable tectono-sedimentary origin has been already mentioned, but not yet confirmed by direct lithological observations. There is a well pronounced structural and metamorphic discordance between the rauhwacke and the underlying Veľký Bok metasedimentary complexes. In the case studied in the Nízke Tatry Mts., this discordance is expressed by the lack of three penetrative deformation stages within the Hronic complexes, which are recorded in the Veľký Bok rocks, and by the skip in estimated PT conditions of deformation in the order of some 5 to 10 km of missing rock column removed from the footwall autochthonous units (cf. PLAŠIENKA, 1995). A conclusion may be drawn that the rear (Veľký Bok) parts of the Krížna unit were already exposed to subaerial erosion and denudation in times when its frontal nappe elements glided subaqueously, on condition that a simultaneous emplacement event of the Hronic nappe system in both areas is assumed (about the time constraints of thrusting events see PLAŠIENKA, 1996). In contrast to 1A tectonites, the overpressured fluids were trapped within the breccia layer bounded by impermeable complexes. Overpressured rauhwacke "pillows" then could reduce vertical stresses and support the weight of the overlying nappe, which facilitated its "smooth" emplacement without any considerable affect on the basement structures.

The 2A-type rauhwackes differ from the previous types by extensive disintegration of the footwall carbonate complexes and their incorporation into the basal nappe crush breccias. The structural-metamorphic discordance at the Muráň nappe sole is even exceeding that of the case of 1B-type contact, indicated by more than 15 km of missing original footwall tectonic overburden (cf. PLAŠIENKA, 1996). We can only hypothesize that the Muráň relief nappe invaded a deeply denuded area with rugged karstic morphology developed in Triassic carbonates of the Veporic Foederata cover unit, which was flattened by basal "rabotage" and dissolution during thrusting.

The 2B-type, ophiolite-bearing breccias, are the least known, though probably most significant tectonites occuring at the Western Carpathian superficial nappe soles. Ophiolitic fragments were obviously derived from the footwall units in time when the Silicic nappes moved over an oceanic suture. They were involved within the mobile basal breccias and then transported above distant paleogeographic domains. Nonetheless, this does not necessarily mean that the allochthonous sheet (the Silica and Stratená nappes in the discussed example) had to be palinspastically located on the other side of the suture (i.e. south of the Meliatic suture in our case, cf. HÓK et al., 1995). It might have followed a curved translation path and ophiolitic clasts might have come not directly from the narrow suture, but from an ophiolitic or mélange nappe in a high structural position, which was later destroyed by erosion. However, paleogeographic considerations are beyond the scope of this paper.

In conclusion, we emphasize that study of clasts included in basal thrust breccia tectonites may provide important information concerning their origin, and about emplacement mechanisms and translation paths of the overlying allochthonous sheets. From our observations we can infer differences in thrusting mechanisms between frontal and rear parts of the Fatric and especially Hronic nappes, being induced most probably by the subaqueous vs. subaerial position of the substratum during thrusting, respectively. The extensive incorporation of substratum units into thrusting processes of the Silicic nappe system suggests these to be typical relief nappes differing from the previous ones not only by the mechanism, but possibly also the time of their final emplacement (PLAŠIENKA, 1996).

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