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series of the southern Black Forest (Germany)

Implications for the Gondwana/Laurussia puzzle

Possible glaciomarine diamictites in Lower Paleozoic series of the Southern Black Forest (Germany): implications for the Gondwana/Laurussia puzzle

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With 5 figures

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Abstract: In the Southern Black Forest, the marine Lower Paleozoic metapelites and metagraywackes of the Badenweiler-Lenzkirch zone contain a well-defined intercalation of diamictites that is characterized by pebble- to block-sized clasts. Although these sediments were subject to low- to medium-grade metamorphism and pervasive deformation, some criteria suggesting a glaciomarine origin for these diamictites are recognized. Clast sizes vary greatly and include some particularly large blocks. The occurrence of diamictites is restricted to a discrete horizon with a considerable lateral extent that is intercalated in a basinal shaly-sandy graywacke sequence. The diamictite clasts consist of plutonic, volcanic, sedimentary, and metamorphic rocks, reflecting a heterogeneous continental source area, presumably a part of northern Gondwana.

Zusammenfassung: Die altpaläozoischen Metasedimente der Badenweiler-Lenzkirch-Zone enthalten einen markanten Diamiktit-Horizont, für den eine glaziomarine Bildung in Betracht gezogen wird. Kriterien sind die stark variierenden Größen der Gesteins- und Mineralklasten bis hin zu Blöcken, die als Fallsteine (dropstones) zu deuten sind. Das abrupte Einsetzen und Enden der gröbklastischen Sedimentation und ihre beträchtliche laterale Erstreckung sprechen ebenfalls für eine solche Erklärung. Trotz der starken tektonischen und metamorphen Überprägung ist eine Mehrzahl plutonischer, vulkanischer, sedimentärer und metamorpher Gesteinsarten

erkennbar, die das Abtragungsgebiet auf einem vermutlich zu Gondwana gehöri-gen Kontinentalbereich repräsentieren.

Key words: Black Forest, Zone of Badenweiler-Lenzkirch, Lower Paleozoic, glacio-marine sediments, diamictite, Gondwana.

Introduction

The Badenweiler-Lenzkirch zone (BLZ) of the Southern Black Forest consists of Paleozoic metasediments, non-metamorphic sediments and volcanics (Fig. 1). This zone is 40 km long and up to 5 km wide. It separates the gneisses, migmatites and metagranites of the Central Black Forest to the north from the gneisses and granites of the Southern Black Forest. The contacts of the Paleozoic metasediments of the BLZ and the adjacent basement units are clearly tectonic and thus display the characteristics of a Variscan suture between two different pre-Variscan terranes (LOESCHKE et al. 1998).

Amongst the metamorphic constituents of the BLZ, the unit of Gschwend-Sengalenkopf (UGS) occupies a position close to the northern border of the BLZ (ALTHERR & MAASS 1977; WERLING 1986); its total known length is 22.5 km and its maximum width is 1 km. It consists of metapelites and metagraywackes which contain a discrete intercalation of diamictites ("metaconglomerates"). The rocks have been subject to strong, mostly ductile deformation and metamorphism up to the amphibolite facies. The occurrence of deformed andalusite and cordierite knotenschiefer indicates a LP-MT event prior to the ductile overprint. Towards the South, less metamorphic and mostly cataclastic metagraywackes and metapelites adjoin the UGS (units of Utzenfeld, Wasserloch, and Bernau of Fig. 1). Towards the north, the UGS is mostly in direct contact with the "Randgranit", a heterogeneous, tectonically deformed metagranite body of Early Carboniferous age (WERLING & ALTHERR 1986). The tectonic circumstances, however, are not dealt with in the present paper as they have been lately analysed by MONTENARI & MAASS (1996) and HANN & SAWATZKI (2000).

Metapelites, metagraywackes and pebble-bearing diamictites

Within the unit of Gschwend-Sengalenkopf, diamictites have first been recognized and described as metaconglomerates by EMMERMANN & SITTIG

(1975, 1977). They occur, as far as the exposures permit to judge, as an up to several tens of metres thick discrete intercalation in a sequence of dark metapelites and silty to fine sandy metagraywackes. In the section W of Sengalenkopf, where tectonic stacking seems to account for the thickening of the sequence, the diamictite horizon appears twice, probably due to its imbrication (BRABENEC 1998).

Metapelites and metagraywackes

In sufficiently large outcrops, the metapelites and metagraywackes are characterized by parallel bedding and lateral bed continuity (e.g. in the quarry at Wacht and elsewhere, cf. SCHÄFER 1957). Major sedimentary features, such as cut-and-fill and slump structures, as well as large-scale foresets could not be observed. Conglomeratic layers and lenses are conspicuously absent in this environment. Although small climbing ripple marks are evident at the top of some sandy-silty layers, graded bedding, bioturbation, sole marks, de-watering structures and shaly rip-up clasts have not been detected. Nevertheless, the regular decimetric to metric interbedding of sandy-silty and shaly layers indicates a low-energy, probably basinal depositional environment. Tentatively this sequence is interpreted as representing a distal basin-plain turbiditic fan complex.

Recent palynological analyses by HANN, SAWATZKI & VAIDA (1995) and HANN & SAWATZKI (1998) indicate Ordovician and Silurian ages for these metapelites and metagraywackes, while MONTENARI & MAASS (1996) and MONTENARI, SERVAIS & PARIS (2000) insist that only Silurian fossils could be reliably identified. Field evidence shows a close association of the diamictites with those sediments, but does not allow a definite statement on its proper stratigraphic position in the sequence. As the diamictites themselves could not be dated palynologically, the question about their age so far still remains open.

Diamictites

In all outcrops, the diamictites ("metaconglomerates") and pebble-bearing metagraywackes of the UGS are highly compacted and often very strongly deformed (Fig. 2). Many of the pebbles have been significantly stretched and reach length to thickness ratios of up to 30; only feldspar-rich plutonic rocks have preserved more ellipsoidal to nearly isometric forms (Fig. 3 and 4). Since entire clasts cannot be separated from their matrix, and since their geometry has often been seriously overprinted, it is impossible to verify

Fig. 2. Strongly deformed pebbles, mostly leucodacite, in metagraywacke, Kleiner Stutz near Utzenfeld. Width of the block 60 cm.

whether they were faceted and scratched, as is otherwise a typical feature of glacially transported pebbles.

The diamictites are characterized by very poor sorting of their components, ranging in diameter from less than a centimetre to rare metric scale blocks; these are embedded in a sandy-shaly, now metamorphosed matrix. Although the size distribution of the pebbles cannot be readily determined, the volumes of individual pebbles can be estimated and then classified in a granulometric system. Thus, most of the pebbles seem to belong to the classes of fine to medium gravel (diameter range between 4 and 64 mm). However, occasionally pebbles of much greater volumes have been found. The phenomenon of irregular grain size distribution extends also into the finer fractions and the microscopic range (Fig. 5).

The volume percentage of pebbles in the diamictites varies within wide limits. Although there are densely packed diamictites, mostly containing relatively large pebbles, irregularly distributed pebbles of different sizes in a

predominant metagraywacke or metapelitic matrix are more frequent. The most conspicuous “tilloid” structures are seen in cliffs and blocks on the northern and northwestern flanks of Sengalenkopf and at the foot of Kleiner Stutz W of Geschwend (positions R23650/H96700, R22730/H96880 and

Fig. 3. Angular granitoid pebble, 10 x 6 cm, possible dropstone encased in pebble-bearing metagraywacke. Same locality as Fig. 2. Dark coating on a joint interrupts the otherwise fresh fracture face.

Fig. 4. Trondhjemite pebble, 10 x 6 cm, possible dropstone in pebble-bearing meta-graywacke. Same locality as Fig. 2.

R19550/96860, respectively; topographical map 8113 Todtnau 1:25 000). In the same areas, field evidence suggests most clearly the episodic development of the coarse diamictites. In other sections, metapelites and meta-graywackes containing less frequent and smaller pebbles prevail.

Due to deformation and metamorphic recrystallization, other sedimentological details such as the degree of rounding, grain size of the original matrix, graded bedding, ripple marks and others can hardly be observed. Nevertheless, the majority of the pebbles are clearly outlined against neighbouring ones and the matrix and can thus be defined on the basis of their particular composition and structure.

Pebbles contained in the diamictites consist of a wide range of plutonic, volcanic, sedimentary, and metamorphic rocks. As such, they were clearly derived from a continental basement that is presumably considerably older than Ordovician. A petrographic analysis of the diamictite components

indicates the occurrence of the following lithologies, expressed in terms of their supposed non-metamorphic protoliths:

- Trondhjemitites: coarse- and fine-grained; not very frequent as pebbles, but predominant as sources of the abundant plagioclase and quartz clasts of the metagraywackes.
- Graphic intergrowths of plagioclase and quartz: most probably from trondhjemitic environments; rather rare.
- Gabbro: rare.
- Rhyolite: different varieties; with phenocrysts of plagioclase and quartz; mostly strongly deformed; frequent.
- Leucodacite: several varieties; mostly with plagioclase phenocrysts; frequent.
- Andesite and related rocks: different varieties, characterized by plagioclase phenocrysts up to 1 cm long, a few of them with relics of repeated zoning (cf. WERLING 1986); frequent in some exposures.
- Basaltic rocks (now amphibolites): not frequent.
- Vein quartz: different varieties; frequent.
- Quartz-rich sandstones: many varieties; quite frequent.
- Chert: rare.
- Siltites and pelites: many varieties; frequent.
- Graphite-bearing pelites: frequent.
- Carbonate-bearing psammitic or pelitic sediments (now diopside bearing metamorphic rocks): frequent in some exposures.
- Gneisses: rare.

Judging by the variety of rock and mineral clasts observed in the diamictites and metagraywackes, their source area probably consisted of a complex system that included a) a basement complex characterized by granitoids and other plutonites and some gneisses, b) a "Schiefergebirge" with mostly fine-grained, perhaps low-grade metamorphic clastic sediments, some carbonate-bearing sediments, quartz veins and other constituents, and c) a calc-alkaline volcanic association of rhyolites, dacites, andesites and perhaps some basalts. Such an association could be found in the Precambrian - Early

Fig. 5. Thin section of a pebble-bearing metagraywacke. **Rh** = part of a relatively large rhyolite pebble, **Tr** = trondhjemitite, **Qu** = quartzite, **Mp** = metapelite, **Mpb** = biotite-rich metapelite, **without symbols**: streaks of plagioclase-rich metagraywacke matrix. Horizontal width of figure: 2.1 cm. Same locality as Fig. 2.

Fig. 5 (Legend see p. 507)

Cambrian Panafrican orogenic belt that was associated with the northern margin of Gondwana (VON RAUMER & NEUBAUER 1993, STAMPFLI 1996, VON RAUMER 1998). Radiometric age determinations on plutonic pebbles contained in the diamictites are in preparation. Preliminary results on zircons of a trondhjemite pebble from Geschwend (207/206 Pb method) point to a crystallization age of approximately 790 Ma (pers. comm. Dr. Wolfgang Doerr, Gießen, June 2000).

The occurrence of the above described diamictite intercalation in the otherwise finegrained metapelites and metagraywackes reflects a drastic, though short-term change in the environment of the basin in which they were deposited. Such a change could be either related to glaciation of the source area, or possibly a sharp eustatic drop in sea level, allowing for density currents bearing coarser clastic fragments to advance into the realm of the basin plain. Of these two alternate models, we give preference to a glaciomarine origin of the diamictite.

Criteria supporting a glaciomarine origin of the diamictites

In a number of cases, single conspicuously “oversized” clasts, such as those in the quarry at Wacht near Bernau, raise the question of the mode of their transport and deposition. The largest clast, observed in 1976, consisted of a meta-rhyolite slab that was nearly 2 m long and up to 15 cm thick. It was embedded in a metapelitic to metagraywacke matrix that contained many much smaller pebbles of the same rhyolitic lithology. As this slab formed part of a boulder that had a volume of several cubic metres, it could not be recovered as a whole. Also in the same quarry, a few meta-trondhjemitic pebbles of up to 15 cm in diameter were found (Fig. 3 and 4). Some other particularly large pebbles occurred in other exposures, e.g. on the northern flank of Sengalenkopf. These are the extreme members of a very wide range of pebble sizes that extends from volumes much below 1 cm³ to others in the hundred to thousand cm³ classes.

Whilst the single oversized clasts are the most likely candidates for dropstones, the very irregular granulometry of the entire diamictite deposit is also indicative of its glaciomarine transport and deposition. As far as the discontinuous exposures allow to observe, the diamictite horizon appears to extend - although heterogeneous in details of its structure and composition - over the entire length of the UGS. As such, the diamictite must be regarded as the product of an episodic event during which abundant material was eroded under glacial conditions from a continental source region, and was transported by floating ice rafts into an adjacent marine basin where these melted and released their clastic load.

A further criterion for the prevailing climatic conditions of that epoch is the high proportion of fresh plagioclase clasts and plagioclase-rich rocks (e. g. andesite) in the metagraywackes and the diamictite itself. This indicates that the source area of the clastics was subjected to predominantly physical weathering under a cold climate.

The alternative interpretation of the diamictite as a density current deposit seems less appropriate. Such currents are tied to more or less discrete entry points; their coarser load is generally deposited in proximal fans that are characterized by rapid lateral thickness and facies changes. Moreover, a density current fan model is unlikely to account for the sharp onset and termination of the diamictite deposition, barring the assumption of a very short-term major drop in sea-level.

Conclusions

It is proposed that the diamictite layer that occurs in the Lower Paleozoic metapelites and metagraywackes of the Geschwend-Sengalkopf unit in the Badenweiler-Lenzkirch Zone is of glacio-marine origin. As such, it would fit very well into the system of similar Late Ordovician glacial formations known from e. g. Thuringia, the Armorican Massif and Iberia, as well as from Northern Africa (HAMBREY 1985, LÜTZNER et al. 1986, ROBARDET & DORÉ 1988, KATZUNG 1999). Paleogeographic considerations lead to a model according to which the series of Geschwend-Sengalkopf were deposited in a deeper water basin, located along the periphery of the disintegrating Gondwana continent and its fragments. Presumably during the Silurian, this terrane was detached from Gondwana and later accreted to Laurussia. Implications of such an interpretation are that the Badenweiler-Lenzkirch Zone forms either part of the larger and probably composite Gondwana-derived Armorican and Bohemian-Saxothuringian terrane, or represents a separate terrane (ZIEGLER 1986, 1989, 1990; TAIT et al. 1997, MONTENARI 1999).

Traditionally, the central parts of the Black Forest have been assigned to the Moldanubian Zone of the Variscan orogen, with the Badenweiler-Lenzkirch Zone forming the suture between it and the southward adjacent Southern Black Forest Zone, possibly representing a separate terrane that probably correlates with the Drosendorf unit of the southern Bohemian Massif (LOESCHKE et al. 1998, PHARAOH 1999). Assuming that the sediments of the Badenweiler-Lenzkirch Zone form part of this southern terrane, the interpretation advanced here indicates that also this terrane is Gondwana-derived.

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References

- ALTHERR, R. & MAASS, R. (1977): Metamorphite am Südrand der Zentralschwarzwälder Gneismasse zwischen Geschwend und Bernau. – N. Jb. Geol. Paläont., Abh., **154**: 129-154; Stuttgart.
- BRABENEC, M. I. (1998): Metamorphe Gesteinsassoziationen im Gebiet von Todtnau-Geschwend in der Badenweiler-Lenzkirch-Zone (BLZ); Detailkartierung, Zusammenhänge und Neuigkeiten. – Diplomarbeit, 123 pp.; Freiburg i. Br.
- EMMERMANN, R. & SITTIG, E. (1975): Zur Frage des kalifeldspatisierten Devons von Geschwend (Südschwarzwald). – N. Jb. Geol. Paläont., Mh., **1975**: 193-202; Stuttgart.
- (1977): Transgressive Paleozoic on the Central Schwarzwald gneiss core. – N. Jb. Geol. Paläont., Mh., **1977**: 129-136; Stuttgart.
- HAMBREY, M. J. (1985): The late Ordovician - early Silurian glacial period. – Paleogeogr. Paleoclimatol. Paleoecol., **51**: 273-298; Amsterdam.
- HANN, H. P., SAWATZKI, G. & VAIDA, M. (1995): Chitinozoen und Acritarchen aus metamorphen Grauwacken der Zone Badenweiler-Lenzkirch, Schwarzwald, SW-Deutschland. – N. Jb. Geol. Paläont., Mh., **1995**: 375-383; Stuttgart.
- HANN, H. P. & SAWATZKI, G. (1997): Geologische Karte von Baden-Württemberg 1:25 000, Blatt 8313 Zell im Wiesental, vorläufige Ausgabe; Stuttgart.
- (1998): Deckenbau und Sedimentationsalter im Grundgebirge des Südschwarzwalds/SW-Deutschland. – Z. dtsh. geol. Ges., **149**, 183-195; Stuttgart.
- (2000): Neue Daten zur Tektonik des Südschwarzwalds. – Jber. Mitt. oberrhein. geol. Ver., N.F. **82**: 363-376; Stuttgart.
- KATZUNG, G. (1999): Records of the Late Ordovician glaciation from Thuringia. – Z. dtsh. geol. Ges., **150**: 595-617; Stuttgart.
- LOESCHKE, J., GÜLDENPFENNIG, M., HANN, H. P. & SAWATZKI, G. (1998): Die Zone Badenweiler-Lenzkirch (Schwarzwald): Eine variskische Suturezone. – Z. dtsh. geol. Ges., **149**: 197-212; Stuttgart.
- LÜTZNER, H., ELLENBERGER, J. & FALK, F. (1986): Entwicklung der Sedimentationsrate und der Ablagerungsprozesse im Altpaläozoikum Thüringens. – Z. geol. Wiss., **14**: 83-93; Berlin.
- MONTENARI, M. (1999): Palynologische Untersuchungen an metasedimentären Einheiten des Schwarzwaldes. – Diss., 221 pp.; Freiburg i. Br.
- MONTENARI, M. & MAASS, R. (1996): Die metamorphen Schiefer der Badenweiler-Lenzkirch-Zone/Südschwarzwald. Paläontologische Altersstellung (Acritarchen und Chitinozoen) und Tektonik. – Ber. naturforsch. Ges. Freiburg i. Br., **84/85**: 33-79; Freiburg i. Br.

- MONTENARI, M., SERVAIS, T. & PARIS, F. (2000): Palynological dating (acritarchs and chitinozoans) of Lower Paleozoic phyllites from the Black Forest/south-western Germany. – *C. R. Acad. Sci. (Paris), Sciences de la Terre et des planètes*, **330**: 493-499; Paris.
- PHARAOH, T. C. (1999): Palaeozoic terranes and their lithospheric boundaries within the Transeuropean Suture Zone (TESZ): a review. – *Tectonophysics*, **314**: 17-41; Amsterdam.
- RAUMER, J. F. v. (1998): The Palaeozoic evolution of the Alps: from Gondwana to Pangaea. – *Geol. Rdsch.*, **87**: 407-435; Stuttgart.
- RAUMER, J. F. v. & NEUBAUER, F. (1993): Late Precambrian and Palaeozoic evolution of the Alpine basement - an overview. – In: RAUMER, J. F. v. & NEUBAUER, F. (Eds.): *Pre-Mesozoic geology of the Alps*: 625-663; Berlin (Springer).
- ROBARDET, M. & DORÉ, F. (1988): The late Ordovician diamictitic formations from southwestern Europe: North Gondwana glaciomarine deposits. – *Paleogeogr. Paleontol. Paleoecol.*, **66**: 19-31; Amsterdam.
- SAWATZKI, G. (1992): *Geologische Karte von Baden-Württemberg 1:25 000, Blatt 8214 St. Blasien*, with explanations, 157 pp.; Stuttgart.
- SCHÄFER, M. G. (1957): *Die devonischen Sedimente der Südschwarzwälder Hauptbewegungszone*. – Inaug.-Diss., T.H. Stuttgart, 87 pp; Stuttgart.
- STAMPFLI, G. M. (1996): The Intra-Alpine terrane: a paleothryan remnant in the Alpine Variscides. – *Eclogae geol. Helv.*, **89**: 13-42; Basel.
- TAIT, J. A. , BACHTADSE, V., FRANKE, W. & SOFFEL, H. C. (1997): Geodynamic evolution of the European Variscan fold belt - paleomagnetic and geological constraints. – *Geol. Rdsch.*, **86**: 585-598; Stuttgart.
- WERLING, E. (1986): *Die tektonische und metamorphe Entwicklung am Südrand der Zentralschwarzwälder Gneissmasse bei Bernau*. – Diplomarbeit, 121 pp; Karlsruhe.
- ZIEGLER, P. A. (1986): Geodynamic model for the Paleozoic crustal consolidation of Western and Central Europe. – *Tectonophysics*, **126**: 202-228; Amsterdam.
- (1989): *Evolution of Laurussia: a study in Late Paleozoic plate tectonics*. – Kluwer Acad. Publ., 102 pp and 14 plates; Dordrecht.
 - (1990): *Geological Atlas of Western and Central Europe*, 2nd edition, 239 pp. + 56 plates; Shell internat. Petrol. Maatschapp, distributed by Geol. Soc. London, Publishing House, Bath.

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